Annex A14.16 Pipelines Engineering Justification Paper

December 2019

As a part of the NGGT Business Plan Submission

nationalgrid

Executive Summary

Introduction

To maintain the ongoing safe, secure and reliable operation of the UK Gas National Transmission System (NTS), it is imperative that the health of the assets that constitute the NTS is carefully managed.

Our Asset Health programme is an ongoing plan of works that assures this and consists of 7 core asset themes of work. This document outlines our approach to the management of our Pipelines assets to meet desired regulatory, stakeholder and financial outcomes. A 10-year view has been taken, covering the RIIO-2 and RIIO-3 regulatory periods to ensure a balanced, lifecycle approach to asset management.

Our Pipelines Asset Health plan is built on robust data that has been gathered over many years. Our programme is driven by primary legislation and managed through an accepted methodology agreed with the [redacted]. Significant pipe replacement or coating reapplication to address defects would be too expensive for customers, so the most cost-efficient solution is a regime of internal and ground-based surveys combined with investment in cathodic protection and the associated investigation and remedial works to prolong the life of the assets.

The Pipelines asset health programme is split across 5 sub-themes. In total, we propose £143.5m of investment (23.3% of the 7 themes that comprise the overall asset health plan) ensuring risk levels are maintained on our Pipeline assets during RIIO-2.

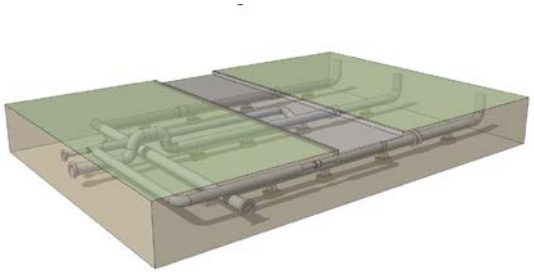
Sub-theme	Intervention Volumes	Cost
Depth of Cover	317	£1,081,724
Impact Sleeves	62	£4,642,360
PIG Traps	93	£4,267,913
Pipeline, Coating and CP	9,682	£131,440,882
Watercourse Crossings	19	£2,100,046
Total	**10,173**	**£143,532,925**

The profile of Pipeline asset health investment for the 10-year period, derived from the volumes of work and the unit costs, is shown in the table below:

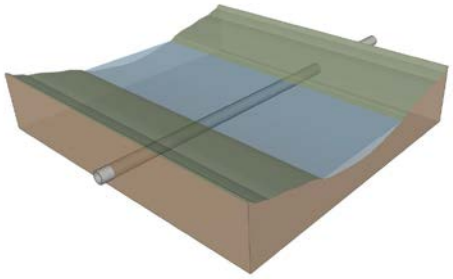
Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Total	20,124	26,911	32,039	30,770	33,689	32,565	34,630	28,836	28,421	29,683
	143,533					**154,135**				

The Assets

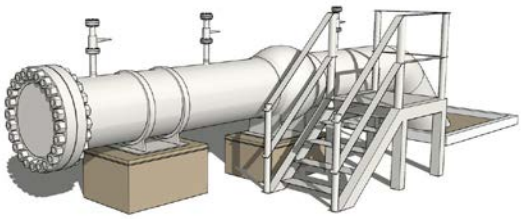
The pipeline assets comprise ~7,600km of mostly buried **Pipeline** which is **Coated** as a primary means of corrosion prevention and protected by **Cathodic Protection** as a secondary means. **Protection Sleeves** guard the pipeline at locations of high risk such as road crossings. **PIG Traps** allow in-line inspection (ILI) of below ground pipeline without requiring an outage. In addition, the monitoring of the **Depth of Cover** of the buried pipeline both on dry land and at **Water Course Crossings** is included in this document.



Below Ground Pipework



River crossings



Pipeline Inspection Gauge (PIG) Trap

Cathodic Protection Test Post & Transformer Rectifier Cabinet

Pipelines are the primary asset within the NTS that enable transportation of gas and maintaining the integrity of these assets is critical to the safe and reliable operation of the NTS. The design, construction, operation and maintenance of our pipelines are subject to both the Pressure System Safety Regulations 2000 (PSSR) and Pipeline Safety Regulations 1996 (PSR). We have an obligation to complete the necessary maintenance activities, under these regulations, to manage the process safety risks that are associated with operating high-pressure natural gas pipelines.

For some of the pipeline network, alternative gas paths are available. However, there are many sections where redundancy is not present, and these pipelines represent a single point of failure. Also, a high proportion of our pipeline network is buried, and the remote and hidden nature of the asset makes it time consuming and expensive to inspect and maintain. The key technical challenges for the pipeline are:

- Corrosion as the primary degradation mechanism is managed through robust inspection and mitigation strategies, carrying out ILI runs (i.e. in-line inspections), maintaining coating protection and cathodic protection;
- Third party interference which can potentially damage the pipeline is addressed by having appropriate depth of cover, water course crossings and protection sleeves, where appropriate, and pro-active and reactive maintenance regimes.
- PIG traps deteriorate with age and use. They require on-going care to maintain their condition and must be available to enable regulatory safety compliance to deliver our In-Line Inspection requirements

Most of the pipeline is over 40 years old and it is external corrosion defects and damage that limit the life of the asset. Coatings are generally degrading which puts more emphasis on the performance of Cathodic Protection systems to limit defect growth. However, these systems need increasing maintenance and upgrading to meet a growing performance demand.

Impacts of no investment

Lack of investment would result in an unsustainable situation. The volume of corrosion defects will grow to a level where the performance on the NTS cannot be maintained, and any level of remediation would not keep pace with degradation. This would place the NTS in a state where only significant asset replacement would counter the corrosion issues, at significant cost to customers and consumers.

Proposal Development

Overall, there is no tenable option for significant pipe replacement or coating reapplication – this is simply too expensive for our customers. Therefore, a regime of internal and ground-based surveys combined with investment in effective Cathodic Protection and the associated investigation and remedial work, is by far the most cost-efficient solution to manage the long-term health and legal compliance of this critical asset. This regime delivers the identified outcomes and results in a significant cost-benefit over the life of the period considered.

In defining our proposed intervention approach, we have considered (where applicable) a range of Programme Options for each asset sub theme and compared these against a baseline option that assumes a reactive intervention stance only. Each baseline option only includes reactive operating expenditures (opex) spend that is necessary as RIIO-2 develops, with no capital expenditure (capex) spend. The implication of this approach for below-ground pipelines is that all resolution of defects identified through In-line Inspections (ILI) are treated as proactive capex spend and **do not form part of the baseline option**. The number of ILI defects has been predicted based on historical experience and actual numbers are not known until in-line inspections are completed. The baseline option assumes that these defects are not repaired and we then apply proactive interventions to resolve defects in line with internal policy and legislative requirements. If we treated these defect repairs as reactive, we would be including significant level of investment in our plan which had not been subjected to cost-benefit analysis. In addition, these repairs would also become part of the monetised risk baseline and if more, or less, were undertaken during RIIO-2 could distort measurement of NARMs performance. In deciding on the proposed intervention strategy, we have considered the ability to meet the desired engineering and stakeholder outcomes and the resulting cost-benefit.

In choosing the option to be carried forward into our plan we have considered the results of our CBA analysis amongst a range of other factors as outlined below:

- The need to achieve legislative compliance may not necessarily be reflected through the quantified benefits delivered through a cost beneficial investment option, for example, the [redacted] will not tolerate a planned increase in safety risk, regardless of the economics.
- Where there is a backlog of known asset failures to be resolved, this will not always be reflected by the CBA as the risk valuation is calculated using an expected rate of future defects across the whole population of an asset type.
- Our understanding of individual asset condition has improved during RIIO-1 but there will always be unknown issues. Our plan reflects the need for a practical mix of intervention categories once specific assets are surveyed and their true condition and risk are understood. For example, a plan based upon 100% refurbishment may require a high number of replacements should a proportion of the assets be determined as non-serviceable.

- The need for a deliverable programme of work, both in terms of planning outages, resource availability and contract efficiency. For example, through "bundling" work it may be more cost-effective to undertake alternative interventions to achieve reductions in contract costs, minimise outage risks or avoid an early repeat intervention in future RIIO periods.

The table below summarises the key considerations when developing this theme of work.

To deliver these outcomes….
• Maintaining medium and long-term integrity of the pipeline asset at lowest whole life cost. • Ensuring continued compliance with the Pressure System Safety Regulations 2000 (PSSR) and Pipeline Safety Regulations 1996 (PSR) and other legislative requirements. • Preventing corrosion issues resulting in a loss of containment of high-pressure gas, presenting a safety risk, and not limiting the availability or performance of the NTS. • Maintain reliable energy supplies across the NTS • Meeting the expectations of our customers and stakeholders and keeping risk stable
…by intervening like this…
• Continuing to actively manage the coating and cathodic protection of the buried pipelines • Ensuring regulatory inspections are conducted in a timely manner • Investigating and resolving specific areas of risk and damage to the pipeline, cathodic protection systems and associated assets • Dealing with defects to manage the intervention burden at sustainable levels • Reducing planned and unplanned emissions of methane to atmosphere • Ensuring compliance with legal requirements and all relevant regulations and approved codes of practice
…based on this knowledge:
• An asset-specific condition-based review of the results of routine inspections, maintenance and investigations already undertaken • A deep understanding and expertise related to industry standards on the integrity management of buried pipelines • Information pertaining to the volumes of assets that are currently at end of life or forecast to be at end of life during the investment period • Site-specific reviews of the PIG Traps to ensure they support continued implementation of in-line inspection • Site specific reviews of the Protection Sleeves to ensure they continue to guard against damage and protect the public.

RIIO-2 Pipelines Asset Health Investment Proposal Summary

Pipelines Asset Health investment proposal headlines:

- The total RIIO-2 proposed expenditure for this theme is £143.5m
- 98% of our Pipeline programme is based upon interventions to address known defects (17%) and high confidence work volumes based on historical trends (81%).
- 94% of the Pipeline Asset Health proposals deliver NARMs outputs.

- All the Pipeline Asset Health intervention sub-themes have been subject to cost-benefit analysis and all sub-themes are cost beneficial, paying back within the period defined by Ofgem
- Volume confidence is high due to significant historic data and the repeatability of this work

Where appropriate a range of options has been considered for each sub-theme of work:

Sub-theme	RIIO-2 Plan (£)	Percentage of Theme	Options considered	Option summary / considerations
Pipeline, Coating and CP	£131,440,882	91.6%	3	Range of options identified to balance cost/risk detailed within this justification report for this significant area of work.
Impact Sleeves	£4,642,360	3.2%	1	Least whole-life cost option deployed to mitigate high risk issues using grout where ILI defect aligns to nitrogen sleeve. This represents the "do minimum" option to maintain compliance.
PIG Traps	£4,267,913	3.0%	1	Least whole-life cost option to meet PSSR ILI requirements to convert failed PIG traps where possible to portable traps, repairing/replacing failed PIG traps where conversion is not possible. This represents the "do minimum" option to maintain compliance.
Watercourse Crossings	£2,100,046	1.5%	1	Least whole-life cost solution to meet TD/1 standards chosen to mitigate risk through intervention on high risk/defect issues only. This represents the "do minimum" option to maintain compliance.
Depth of Cover	£1,081,724	0.8%	1	Least whole-life cost option deployed to mitigate risk on an ongoing basis (do minimum) in line with legislation

We have estimated unit costs across all our proposed pipeline interventions either from historical outturn data points, from supplier quotations, or from other estimation methods such as extrapolation to similar types of work or from reviewing industry benchmarking data. Our approach has been primarily based top down from final actual costs combined with bottom-up estimating procedures and supplier rates or quotations. We have challenged our costs through internal benchmarking review with current supply chain partners, combined with the use of benchmarking data where this exists.

All unit costs include efficiencies resulting from bundling delivery programmes across asset classes, within available outages and our innovation projects where these are proven to deliver benefits and can be utilised in the planned investments.

83% of costs for pipelines in our plan are supported by historical outturn costs which provides a high level of confidence overall. However, there are several cost differentiators (e.g. diameter, depth of cover, productive hours and length) and unique factors (e.g. repeatable activities, ground conditions, access requirements and work mix), that influence the degree of certainty, which are presented in this report.

A high proportion of our pipeline network is buried, and the remote and hidden nature of the asset can make it time consuming and expensive to inspect and maintain. Other factors such as the diameter and scope of the intervention (e.g. coating versus replacement of sections of pipeline) can all vary by project and impact the cost of works. Similarly, the depth of excavation required to reach a defect for below ground pipeline, and the potential requirement for

temporary access roads to reach the affected asset, are factors that can impact project costs by £200k-£300k per instance and therefore create significant variation in costs.

The table below summarises the evidence used to produce the Pipeline unit costs.

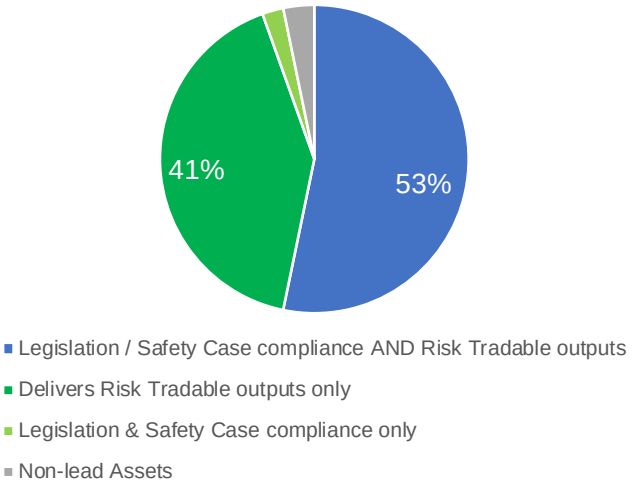
Investment sub-theme	Secondary Asset Class	RIIO-2 Business Plan	Evidence		
			Outturn	Quotations	Other
Depth of Cover	Depth of Cover	£1.1m			100%
Impact Sleeves	Impact Sleeves	£4.6m	68%	32%	
Pig Traps	Pig Trap	£4.3m	83%		17%
Pipeline, Coating & CP	Below Ground Pipe & Coating	£131.4m	86%		14%
Watercourse Crossings	Watercourse Crossings	£2.1m		13%	87%
Total		**£143.5m**	**83%**	**1%**	**15%**

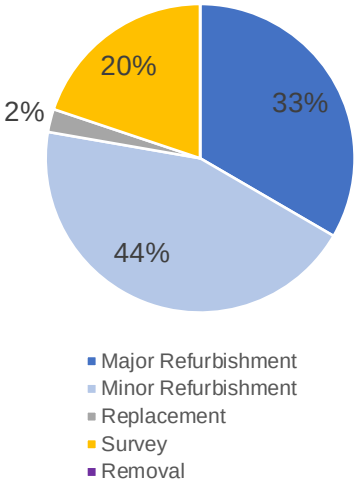
We have set out full details of our process for estimating unit costs across our asset health proposals in our Asset Health Unit Cost Annex.

The RIIO-2 Asset Health Pipelines theme and intervention costs, and volumes by output are provided below. All costs are in thousands (£000s).

Sub-theme & Intervention	RIIO-2 Volumes	Legislation/ Safety Case & Risk Tradable	Risk Tradable	Legislation & Safety Case	Non-lead Assets
Depth of Cover					
Depth of cover (defect resolution)	[redacted]	£0	£0	£1,082	£0
Impact Sleeves	[redacted]				
Nitrogen Sleeve Remediation - Minor	[redacted]	£0	£0	£0	£787
Nitrogen Sleeve - Grouting	[redacted]	£0	£0	£0	£1,475
Nitrogen Sleeve Remediation - Major	[redacted]	£0	£0	£0	£2,381
PIG Traps					
Pig Trap PSSR Defect Resolution - Minor	[redacted]	£711	£0	£0	£0
Pig Trap PSSR Major Inspection	[redacted]	£2,515	£0	£0	£0
Pig Trap PSSR Defect Resolution - Major	[redacted]	£1,042	£0	£0	£0
Pipeline, Coating and CP					
Cathodic Protection (CIPS) Digs	[redacted]	£0	£59,290	£0	£0
Cathodic Protection - AC mitigation	[redacted]	£1,134	£0	£0	£0
Cathodic Protection - remote monitoring	[redacted]	£6,705	£0	£0	£0
Replace existing Transformer/Rectifier	[redacted]	£1,995	£0	£0	£0
Repair/Replace existing CP test posts	[redacted]	£1,772	£0	£0	£0
In Line Inspection Defect Digs	[redacted]	£33,292	£0	£0	£0
In Line Inspection (Pipeline PSSR Inspection)	[redacted]	£18,476	£0	£0	£0
OLI/4 (Pipeline PSSR Inspection)	[redacted]	£158	£0	£0	£0
OLI/4 Pipeline Defect Remediation	[redacted]	£2,154	£0	£0	£0
CIPS for Capital Refurbishment	[redacted]	£3,152	£0	£0	£0
Install new Transformer/Rectifier	[redacted]	£3,314	£0	£0	£0
Watercourse Crossings					
Watercourse crossings (defect resolution)	[redacted]	£0	£0	£1,855	£0
Watercourse crossings (Duddon Estuary)	[redacted]	£0	£0	£245	£0
Total	[redacted]	**£76,418**	**£59,290**	**£3,182**	**£4,642**

Pipelines Asset Health theme outputs and intervention categories:

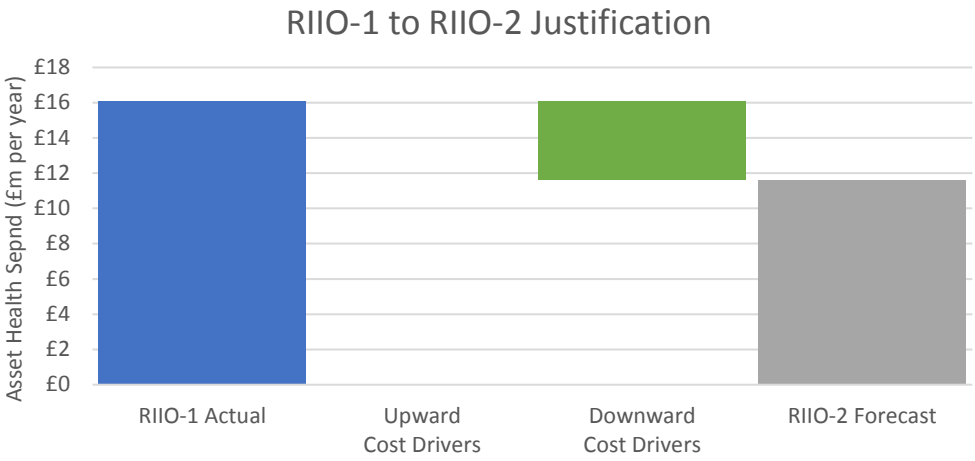




Comparing our RIIO-2 proposal to our RIIO-1 programme

The annualised RIIO-2 spend has increased when compared to RIIO-1 from £16.2m to £26.4m for the Pipelines Asset Health theme.

Note that this cost information is annualised to provide a comparative cost per year and that the total RIIO-2 forecast below also includes the application of our agreed efficiency target within the downward drivers.



The drivers for the increase in spend from RIIO-1 to RIIO-2 stem from increases in volumes rather than increases in unit costs. Our proposed RIIO-2 unit costs are broadly in line with RIIO-1 unit costs (with further efficiencies also added), given that the majority (83%) are estimated from RIIO-1 historical outturn data.

The volume drivers, both upward and downward, affecting our proposed RIIO-2 spend are set out below.

Upward Drivers

The RIIO-1 pipeline strategy focussed on In-Line Inspection defect investigation and remediation as a priority. Our RIIO-2 strategy brings greater volumes of the Close Interval Potential survey (CIPs) defects (an area we are spending over forecasts in RIIO-1) into the plans. This increases the overall cost of the pipelines theme, to dig and remediate potential end of life pipeline coating issues. These issues degrade our Cathodic Protection system effectiveness and failure to act in the nearer term will result in significant pipeline failure risk and/or whole life cost issues. Note that the annualised allowance for RIIO-1 is comparable to what we are requesting for RIIO-2, for all activities except CIPS.

Downward Drivers

Several innovations have been developed in pipelines during RIIO-1 (epoxy sleeves, seam weld identification and others) which will be rolled into RIIO-2. In addition, we found a better way to deal with river crossing asset health risks in RIIO-1, reducing costs significantly from the original RIIO-1 forecast and these lower cost interventions/mitigations continue to feature in our RIIO-2 plan. These have all been built into our proposed unit cost for RIIO-2.

We continue to bundle work around feeder outages which is a primary driver to keep pipeline work costs low, as well as minimising impacts to our customers. Our “Richmond” programme, producing enhanced planning processes, and systems with the integration of all elements of our asset risk and planning data, enables ongoing improvements in this area.

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1. Summary Table

Name of Scheme/Programme	*Pipeline*
Primary Investment Driver	*Asset Health*
Scheme reference/ mechanism or category	*A22.16*
Output references/type	*-*
Cost	*£143.5m*
Delivery Year	*2022-2026*
Reporting Table	*3.03b*
Outputs included in RIIO-1 Business Plan	*-*

2. Introduction

2.1. See the Executive Summary for an overview of the purpose of this investment theme within our overall asset health investment plan.

Structure of the Case

2.2. This document summarises the justification of pipelines assets. The document covers several asset types that collectively make up our pipeline asset base. Each type of asset has been assessed using a consistent overall analytical framework.

2.3. The investment case for each of the individual asset types is set out in the following sections of this document. Our approach for each has been to set out:

2.4. The investment case for Pipelines investment is organised into five groups:

- Pipeline, Coating and CP
- PIG Traps
- Protection Sleeves
- Watercourse Crossings
- Depth of Cover.

2.5. For each group the following structure has been followed:

- **Introduction –** this section with the structure of the case and an overview of the pipelines and their effective management
- **Equipment summary** – which provides a summary and profile of the asset base
- **Problem statement –** the issues facing the assets, drivers for investment and impact of no investment
- **Probability of failure and probability of consequence** – sections which set out the way the assets fail and the subsequent stakeholder impacts
- **Options considered –** the potential mix of interventions to be considered for each of the assets within a range of programmes with differing objectives
- **Business case outline and discussion –** the preferred programme option and reasons, given the cost benefit analyses and assessment of other drivers, stakeholder requirements and business objectives
- **Preferred option and plan –** the final selected option restated, along with the spend profile.

Understanding our Pipeline Assets

2.6. The pipeline asset is a large linear, distributed and connected asset that enables the transmission of gas across the whole of the UK. It connects all entry and exit points on the NTS together with all the compressor sites, above ground installations and block valves.

2.7. The pipeline network was originally designed with a nominal 40-year life to take a homogeneous flow of natural gas from the North to the South of the country with constant flow and pressure.

2.8. There are over 7,600 km of steel pipeline with the majority at diameters ranging from 900mm to 1200mm. The NTS can hold in the region of 350 million cubic meters of gas (linepack) at any one time, with a throughput of up to 440 million cubic meters per day in peak conditions at maximum operating pressures ranging from 70 to 94 bar

2.9. The pipeline asset class consists of the following elements:

- **Pipeline –** enables the flow of gas throughout the NTS. The majority is below ground, although some sections are above ground, or through exposed pits, within AGI's or block valves
- **Coating –** provides primary corrosion prevention for all pipework. Various coating methods are in use depending upon the location and age of the pipeline
- **Cathodic Protection –** provides secondary corrosion protection of the pipeline where the coating has failed
- **PIG Traps -** enable the launching and receiving of internal inspection devices within the pipeline
- **Protection Sleeves -** consist of a secondary larger casing around the pipeline to provide protection of:
    - members of the public from the consequences of failure of a pipe,
    - the pipeline from external interference
    - the pipeline during its construction
- **Above Ground Crossings –** support sections of pipeline which are above ground as part of the pipeline route – there are two pipe bridges on the NTS
- Other elements in the effective management of the Pipeline are the depth to which it is buried both across dry land, **Depth of Cover**, and where it crosses waterways, **Water Course Crossings**. Maintaining this depth of cover is essential to managing the risk of damage to the pipeline by third parties.

Management of Buried Pipeline

2.10. The design, construction, operation and maintenance of the Pipeline is subject to both:

- Pressure System Safety Regulations 2000 (PSSR) – is general legislation for all pressure vessels and defines the regime for setting inspection frequencies and subsequent remediation of defects
- The Pipeline Safety Regulations 1996 (PSR) – is specific legislation for those operating pipelines and places the obligation to manage the safety risks that they present to members of public and NG staff

2.11. The management of buried steel pipelines has been evolving over the last 50 years as their use has increased and issues with their lifecycle management become clear. We have been at the forefront of the evolution of these techniques alongside other pipeline

owners, national bodies and technical experts. We are leading the development of the techniques and policies used due to the large scale, diversity, complexity and age of our Pipeline assets.

2.12. The industry standard for the design, construction, operation and maintenance and decommissioning management of pipelines in the UK is IGEM/TD/1. This is a recognised standard and is published by the Institute of Gas Engineers and Managers and developed by a panel of cross industry technical experts. National Grid and its predecessors have been involved with the evolution of this standard ever since there has been a requirement to transport natural gas in an integrated way across the UK.

2.13. The NTS evolved from initial construction in the late 1960's and was built, operated and managed to the appropriate version of TD/1 in place at the time. Construction practices have developed hand in hand with the standards, ultimately resulting in the evolution of TD/1. Due to this evolution of asset, industry standard and acceptable safety risk, the issues faced by NG on the NTS pipeline are dependent upon when it was installed, as well as the normal issues inherent to a buried steel pipeline.

- Corrosion is unavoidable in a steel pipeline and the management of corrosion issues has developed with time and this is reflected in the evolving standard. Corrosion mechanisms are far better understood allowing the management of them to become more sophisticated
- Coating types and techniques have changed over time as the understanding of the materials and their long-term performance, safety and environmental impact is better understood. For example, a large population of the NTS (4,381km) is coated in coal tar enamel whose performance is time limited
- Depth of cover is the primary protection against third-party damage. Where depth of cover has reduced, there is a higher risk of third-party damage. Whilst the standard has evolved for the minimum cover (from 3ft to 1.2m) for new pipelines, remediation is only required on existing pipelines where cover has been reduced to an unacceptable level. Where the Pipelines cross watercourses there is an increased likelihood of erosion of cover
- Impact protection that further mitigates against external damage at sensitive locations has changed from a Nitrogen Sleeve to heavy wall pipe. Whilst going forward this results in lower whole life cost, NG have a legacy population of Nitrogen Sleeves to manage

2.14. The internal/external inspection and subsequent remediation of pipeline defects or "features" to industry standards (IGEM TD/1), supplemented by NG policies and procedures is accepted by the Health and Safety Executive as an appropriate way of operating a safe pipeline network and complying all relevant legislation.

Pipeline, Coating and CP System (£131.4m)

3. Pipeline, Coating and CP System - Equipment Summary

3.1. The pipeline is a large linear, distributed and connected network that enables the transmission of gas across the whole of the UK. The Pipeline asset enables the flow of gas throughout the NTS. The majority is below ground with some sections are above ground, or through exposed pits, typically within AGI's or block valves.

3.2. The pipeline is constructed from high strength steel with a wall thickness of between 5mm and 29mm depending on the diameter and design. High strength steel is the only material technically and economically viable to use for these pipelines.

3.3. A buried steel pipeline will corrode, therefore other assets are in place to manage and mitigate this. Whilst there are situations where internal corrosion can occur and must be appropriately managed, most corrosion takes place on the outside of the pipelines. Pipeline Coating applied to the outside surface of the pipeline is the primary corrosion protection for all pipework. Various coating methods are in use depending upon the location and age of the pipeline, these are listed in Appendix 1.

3.4. Cathodic Protection (CP) is installed along the length of every pipeline as secondary protection to prevent corrosion where the coating has failed. The key elements of the impressed current CP systems are the transformer rectifier, ground bed, CP test post and remote monitors.

3.5. Investment in the pipeline cannot be considered in isolation, an integrated strategy across these asset types ensures the lowest whole life cost of the Pipeline.

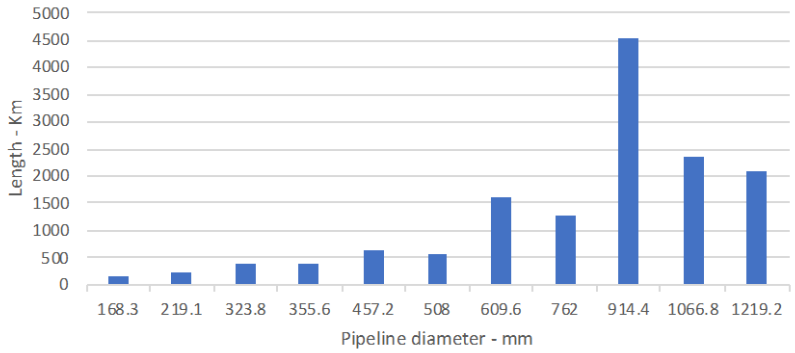
3.6. The design, construction, operation and maintenance of the Pipeline is subject to both:

- Pressure System Safety Regulations 2000 (PSSR) – general legislation for all pressure vessels and defines the regime for setting inspection frequencies and subsequent remediation of defects.
- The Pipeline Safety Regulations 1996 (PSR) – specific legislation for those operating pipelines and places the obligation to manage the safety risks that they present to members of public and NG staff.

Location and Volume

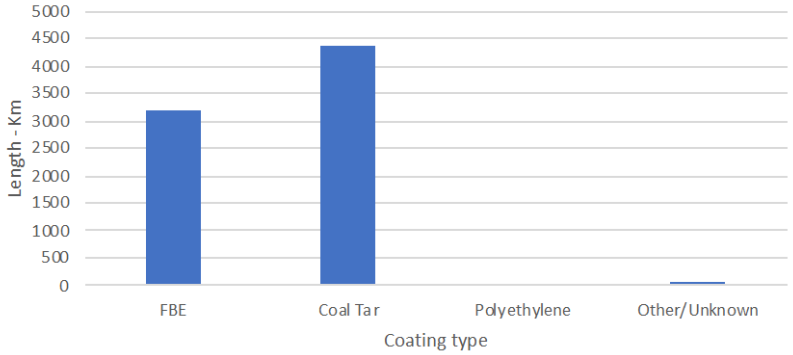
3.7. There are over 7,600 km of steel pipeline with the majority at diameters ranging from 900mm to 1200mm. The figure below shows the length of pipeline split into each of the diameters.

Pipeline Length By Diameter



3.8. The figure below shows the length of pipeline covered by each coating type.

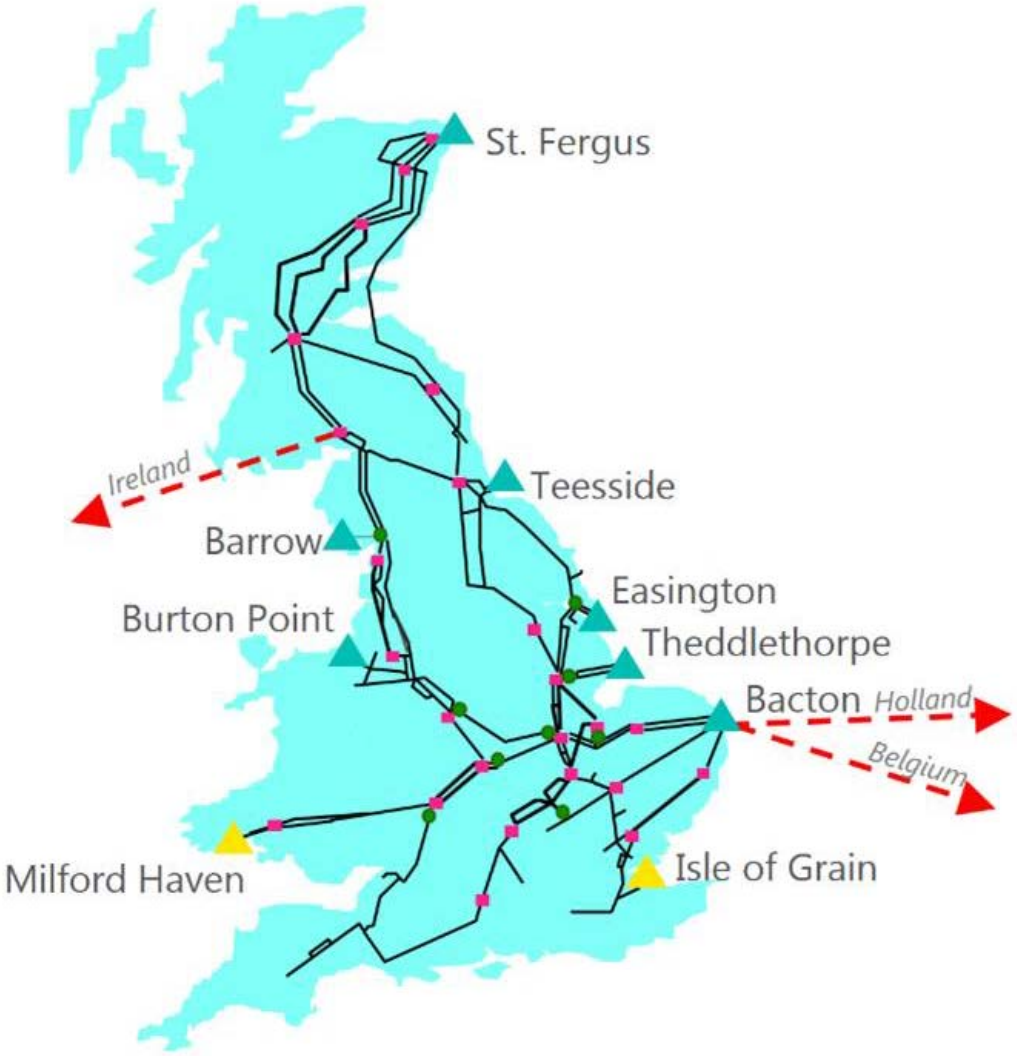
Pipeline Length By Coating



Note: FBE is Fusion Bonded Epoxy (powder coating)

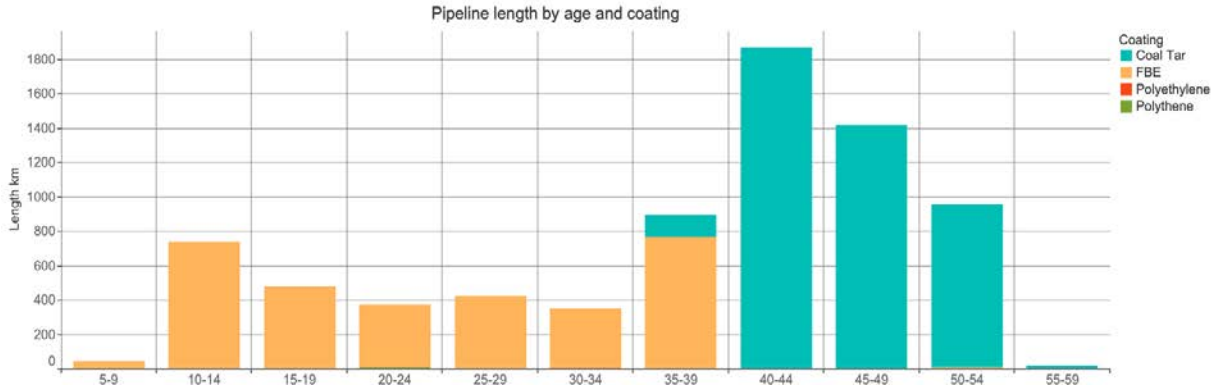
3.9. An overall view of the NTS pipeline is shown in the figure below.

National Gas Transmission System



3.10. The chart below shows the age profile of the pipeline assets with a large proportion of the pipeline at over 40 to 50 years old.

Age Profile of Pipeline Assets



3.11. The coating type used to protect the pipeline from corrosion has changed throughout the last 50 years. Most of the pipeline over 40 years old has a coal tar coating for which there are known issues giving rise to increasing corrosion defects.

Pressure Ratings

3.12. The maximum operating pressure of the pipelines making up the NTS ranges from 70 to 94 barg.

Redundancy

3.13. Although for most of the pipeline network alternative gas paths are available, there are many sections where redundancy is not present, and these represent a single point of failure.

4. Pipeline Coating and CP System - Problem Statement

4.1. Failures of pipelines will directly impact the security of supply for our customers and the safety of members of the public who live, work and travel near our buried assets. The NTS is part of the critical national infrastructure within Resilience UK/UK plc with approximately 80% of the UK energy requirements for heating provided by gas transported via the NTS.

4.2. A buried steel pipeline will corrode and this is the most significant life limiting factor for the Pipeline asset and subsequently the NTS as a whole. Other assets are in place to manage and mitigate the corrosion. Pipeline Coating provides primary corrosion protection for all pipework. Cathodic Protection (CP) is installed along the length of the pipeline as secondary protection to prevent corrosion where the coating has failed.

4.3. Coatings deteriorate with age, with each type having different rates and characteristics and presenting different issues for resolution. More defects are becoming evident on the older coatings (such as coal tar) requiring increasing reliance on the CP systems to compensate and mitigate corrosion.

4.4. In parallel, the CP systems protecting the pipelines are deteriorating. Many have reached the limits of their original design capacity to protect the pipeline from the number and type of coating degradation and defects that are occurring.

4.5. Deterioration and any subsequent failure of the pipeline impacts on several stakeholder outcomes, particularly safety and reliability of the NTS. It is also not affordable to allow the pipeline to deteriorate to a point where it requires significant remediation or replacement.

4.6. The combination of the above will require investment during RIIO-2 to manage the performance of the pipeline in the medium and long term and ensure its continued fitness for purpose as a pressure vessel under PSSR.

Management of the Pipeline Asset

4.7. The most economic approach for the management of pipeline investment is through an inspection regime to understand the integrity of the pipeline and allow investigation and remediation to be targeted. Inspections of Pipelines as a pressure vessel are also mandated in PSSR.

4.8. As over 95% of the pipeline is buried, the inspections are internal and carried out using In-Line Inspection (ILI) equipment. The purpose of in-line inspections is to determine the structural condition of the pipeline providing where necessary, an accurate description of metal loss and other defects which are found. Any defects identified require consideration, investigation and resolution within the defined timescales to comply with PSSR. This can involve exposing the pipeline to identify the remediation work to be undertaken.

4.9. A short length (13km rising to 40km in the investment period) of buried pipeline is not able to be inspected using the in-line inspection equipment. This is due to pipeline configuration not allowing either access to insert equipment or sufficient flows to drive the ILI tool. Potential defects on these are inferred from a combination of a Close Interval Potential (CIP) survey of the effectiveness of the CP system and an electrical survey of the pipeline to check coating integrity. Any abnormalities identified are

combined with other data such as line walk and aerial surveillance results to undertake a risk-based assessment to determine the investigation and remediation timescales. Due to the nature of the survey technique limited information is available without exposing the pipeline, therefore all except the lowest risk abnormalities will require excavation.

4.10. The internal in-line inspections are carried out at defined time intervals. NG use a risk-based scheduling method called Intervals 2, which has been designed to determine the interval to the next in-line inspection based on an estimate of corrosion growth rates, pipeline wall thickness, and stress level in the pipe wall. To do this, Intervals 2 uses pipeline and operational data in conjunction with current and historical Cathodic Protection inspection and test results to establish a rate of degradation and therefore predict when the next inspection is due. This leads to a dynamic interval between each in-line inspection. Intervals 2 is developed by specialist pipeline engineers and used by all UK Gas Transmission and Distribution Operators. It has been ratified by HSE as “accepted practice”.

4.11. A critical factor in the corrosion rate of the pipeline and the condition of the coating is the performance of the CP system. The CP system is in place to prevent the corrosion at any point of the pipeline where the coating has deteriorated. To be effective, the CP system needs to maintain a defined voltage across the length of the pipeline section that it protects. The voltage attenuates with distance away from the CP source, the ground conditions and the number/size of the defects in the coating. The CP systems were generally designed and installed when the pipelines were new with minimal coating defects. As the coating ages and degrades the requirement for CP coverage increases, as more and larger coating defects occur. As the number and size of defects increase, the output of the CP system needs to be increased (tuned) to compensate and maintain the minimum voltage across the length of the section. This is acceptable but has three limitations:

- Each CP system has a maximum capacity
- Increasing the CP voltage too much puts far too much voltage at the start of the CP section which can severely damage some type of coatings, increasing their degradation
- Small defects closer to the start of the section see increasing corrosion rather than reducing corrosion

4.12. The only way to restore effective CP protection is to reduce the distance between the points at which CP is applied (increase the number of transformer rectifiers at the optimal points) so that the voltage (or output) can be maintained across the length of the pipeline without causing coating damage at the start of each section. The placement of these is dependent upon several local factors and each need to be individually designed.

4.13. Most of the CP systems have been tuned as far as possible and now need investment to ensure that they remain effective without presenting a further risk to coating integrity and pipeline corrosion.

4.14. There is evidence that the performance of the CP systems themselves are also deteriorating. As with other electrical assets elements of the CP system deteriorate. However other elements are specifically designed to be sacrificial within the process, such as the ground beds, their deterioration is dependent upon the duty performed

since installation. These issues are specifically prevalent on impressed current CP systems but still apply to some extent on the sacrificial systems.

4.15. Due to the importance of the CP, its effectiveness is assessed through a series of surveys. The results of these are a key part of the assessment of the level of corrosion and therefore metal loss and reduction in the strength of the pipeline. This drives the time to the next in-line inspection for the assets protected by that CP system:

- If cathodic protection performance improves, the inspection interval will increase.

External Studies on the NTS Pipeline

4.16. NG have commissioned two independent studies into the Technical Life of the pipeline asset:

2019 – NTS Pipelines Technical Asset Life – DNVGL

4.17. The key findings of the study are:

- The main time-dependent threats, which have the potential to adversely affect NTS pipeline technical life, are external corrosion and fatigue.
- External corrosion is actively managed and controlled by a combination of external coating and cathodic protection that is subject to regular monitoring to assure its effectiveness.
- The continued fitness-for-service of NTS pipelines with respect to corrosion is assured through an inspect-and-repair regime. This is based on regular In-Line Inspection (ILI), where each pipeline section's inspection interval is set by a semi-quantitative method that includes consideration of the expected corrosion growth rate for that section.
- Pressure cycling of NTS pipelines is regularly monitored and assessed. At the current rate and degree of pressure cycling, the NTS pipeline sections assessed in this study were shown to have fatigue lives which considerably exceed 100 years from 2055.
- If we continue to follow the principles of IGEM/TD/1 and the pipelines continue to be subjected to similar service conditions to those experienced to date, the technical end-of-life of the NTS pipeline sections analysed here can be reasonably expected to exceed 2055 by at least 100 years. Note: the cost of maintenance, including coating repairs and/or CP uprating, may become unacceptable in this timeframe.

2003 – R5923 - Engineering Life of the Pipeline Asset – Advantica (DNVGL)

4.18. R5923 found that, based on almost 39 years of service history:

- Corrosion features on the NTS would be localized and therefore repairable using conventional methods. As such, they do not compromise whole-system integrity.
- Maintenance and reinforcement of the cathodic protection system may be required at some stage in the future. This would most likely involve the replacement or addition of Transformer Rectifiers (TRs) and ground beds.

- Localized coating breakdown may occur under the more extreme service conditions e.g. downstream of compressor stations, however, a small-scale coating rehabilitation programme could reverse this situation relatively easily and cheaply (relative to the value of the asset base).
- Regarding the fatigue threat, it was found that most pipelines in the NTS have been hydrotested to the requirements of IGE/TD/1 before commissioning and therefore, have a fatigue life of 15,000 equivalent cycles of 125N/mm2 hoop stress range.

4.19. R5923 concluded that:

- "The design, construction, operation and maintenance practices used on the NTS pipeline network give confidence that there are no time dependent mechanisms which are considered to be a significant threat to the asset life of the NTS pipelines. Thus, it is most likely that the asset life of the NTS pipeline network will be governed by economic factors, such as changes to supply and demand, rather than engineering factors. **No factors have been identified to limit the engineering asset life to below 100 years, provided existing operation and maintenance procedures are continued and the pipeline network continues to be subjected to similar service conditions to those experienced to date."**

Whilst both reports conclude that with industry standard maintenance practices the pipelines have a theoretical life of 100 years. There is no technical and practical option for a managed decline in the pipeline. Its status as a pressure vessel under PSSR means that is either fit for service or not. If not fit for service, then sections would have to be isolated. So thereby maintaining the ongoing compliance and use of the pipeline through our industry standard practices results in the theoretical 100-year life.

Drivers for Investment

4.20. The key drivers for investment in the Pipeline, Coating and CP assets – which impact on these key risks - are:

- Legislation
- Asset Deterioration
- Material and Manufacturing Defects
- External Interference
- Obsolescence.

4.21. In addition to the legal requirements of PSSR, these assets deteriorate over time and with use, which in turn leads to their inability to perform their required function. This can also result in them no longer complying with direct legislative requirements such as PSR.

4.22. **Legislation –** a pipeline is defined as pressure vessel under PSSR. Therefore, compliance with PSSR drives periodic inspections and the need for remediation to be able to continue to utilise the pipeline

4.23. **Deterioration –** the asset is subject to numerous deterioration mechanisms:

- the Pipeline is subject to external corrosion, the associated metal loss and reduction in wall thickness where the coating has failed and increases where the CP system performance is poor
- the Pipeline is subject to internal corrosion and the associated metal loss and reduction in wall thickness. Whilst rare, occurrences must be remediated as required
- AC interface from nearby electrical assets causes corrosion at the points of coating defects as the induced AC leaves the pipeline
- performance of the CP system deteriorates as more coating defects occur
- components within the CP system deteriorate due to age and usage
- the Pipeline suffers fatigue but the pressure cycling on the NTS is currently low and therefore this is not an issue

4.24. **Defects - material**, manufacturing or installation defects impacting the integrity of the Pipeline or its Coating

4.25. **External Interference –** Third Party or Ground Movement - the pipeline is subject to damage by external parties or movement of the ground which reduces the structural integrity of the Pipeline - resulting primarily from dents, work hardening and metal loss

4.26. **Obsolescence -** the existing CP system remote monitoring relies on the externally provided 3G communications network. This is planned to be shut down during the period 2021-2025 requiring an upgrade/replacement to the CP remote monitoring assets to enable them to continue to operate.

Impact of No Investment

4.27. In appraising asset health investment, we have considered how assets can impact several outcomes:

- Reliability risk
- Environmental risk
- Safety risk
- Societal risk.

4.28. A critical part of our appraisal method is to assess the baseline position. This is the position where we do not invest proactively in our asset base (i.e. we undertake legally required inspections and we fix on fail), ensuring any reactive investment meets all PSSR, PSR and health and safety requirements. The baseline position under each area of spend is reactive opex only, with no capex included in the baseline. This is a baseline against which the incremental investment (in capex and/or opex) is compared to the incremental benefits. This is critical for developing value for money business plans.

4.29. In understanding the baseline position, we recognise that the management of corrosion through coatings and cathodic protection is not exact, although it is recognised that long term deterioration of the asset may still occur in certain areas. However, if

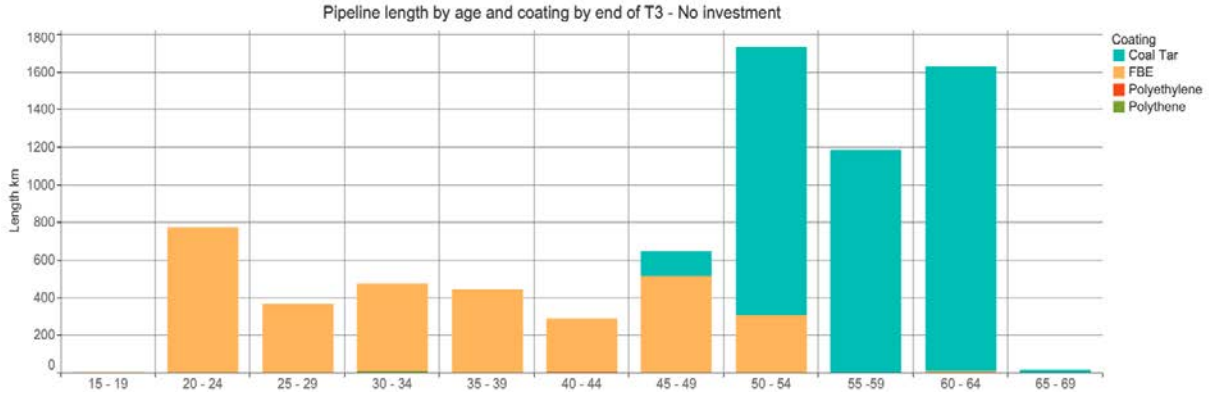
investment is maintained to implement the practices within recognised legal and industry standards the level of defects can be maintained without impacting the long-term performance and safety of the NTS.

4.30. Lack of investment in the pipeline inspections and the associated defect remediation will breach the legal requirements of PSSR, rendering the pipeline unable to be used. Lack of investment in CP systems will increase the number of new corrosion defects and increase the rate of growth of the existing defects. This will drive a higher inspection frequency and numbers of subsequent remediations.

4.31. Continued lack of investment will result in an unsustainable situation where the volume of inspections rises to a significant uneconomic level and exceeds the capability of the NTS to support their delivery without seriously impacting gas supplies. Corrosion defects will also continue to grow to a level where the performance on the NTS cannot be maintained and any level of remediation would not keep pace with degradation. This would place the NTS in a state where only significant asset replacement would counter the corrosion issues.

4.32. The chart below shows the external coating for the pipeline assets and their age profile at the end of RIIO-3, over 59% (4,534 km) of the pipeline will be over 40 years old and 675km of the pipeline will have achieved 60 years of service.

Pipeline length by age and coating by end of RIIO-3 – No Investment

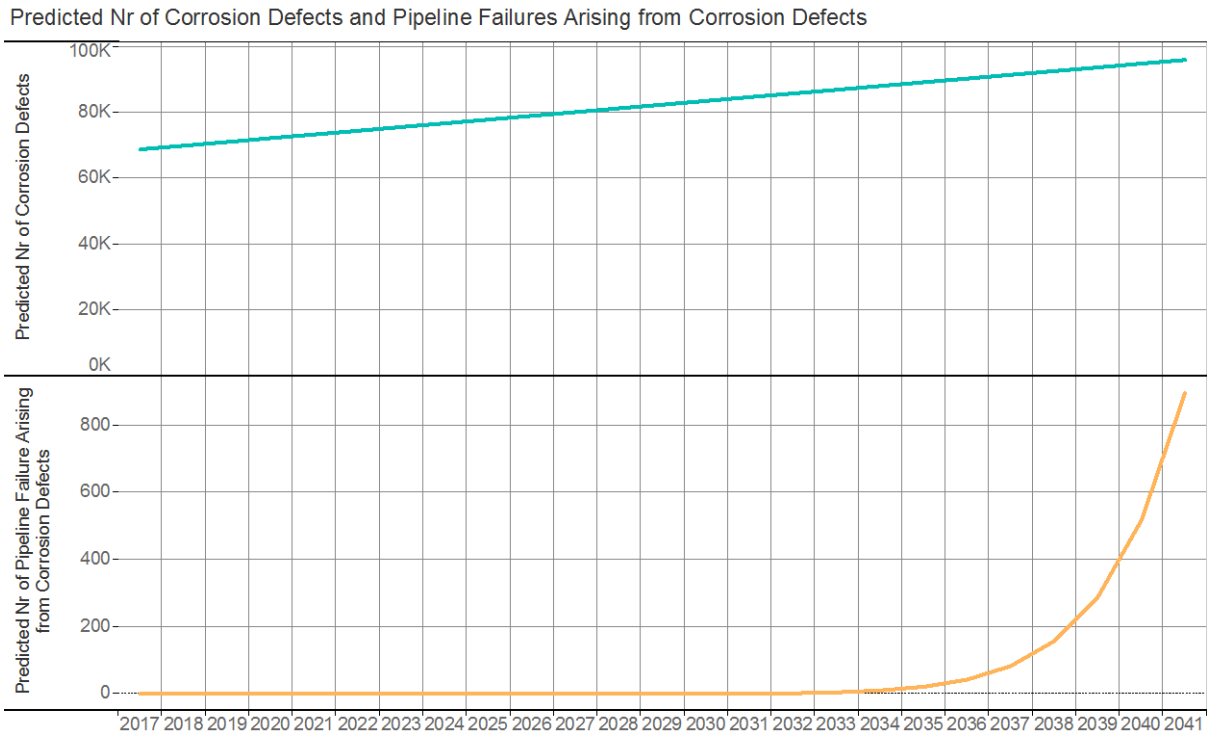


4.33. The number of pipelines with CP systems not providing adequate protection would rise from 53 to 83 out of a total of 154. This will put 4,381 km (over 50%) of pipeline at risk of increased corrosion and/or coating damage.

4.34. In further understanding the impact of lack of investment, we have used the same probability of failure and probability of consequence estimates, and forward-looking predictive assessment as used in developing proposed options for investment.

4.35. Using our analysis tools we predict a rise in the number of corrosion defects. More importantly the existing defects would become considerably worse leading to a significant increase in the probability of a pipeline failure. Any failure of the pipeline will lead to unacceptable health and safety, availability, environmental and societal impacts.

Predicted number of Corrosion Defects and Pipeline Failures arising from Corrosion defects



4.36. The charts above show the predicted number of corrosion defects (features identified from ILI runs) and the expected corrosion related pipeline failures. The current 70,000 features are assessed and result in 6,902 current monitored external metal loss corrosions.

4.37. Our stakeholders and consumers tell us that safety, reliability and affordability are their top priorities. Stakeholders are aware of the risks and the crucial role of the gas transmission system. Without it, much of industry would be without energy and the public would be without heating.

4.38. We have discussed with our stakeholders a range of options around asset health. Stakeholders are clear that they do not want to see any reduction in the level of reliability or increase safety risk and would welcome continual improvements.

Desired Outcomes

4.39. The desired outcome of the investment during the period is to:

- Ensure the pipeline is fit for purpose and able to meet our service obligations to our customers to move gas on and off the network
- Maintain medium and long term integrity of the pipeline asset at lowest whole life cost through the management of the coating and cathodic protection of the buried pipelines.
- Ensure continued compliance with PSSR and PSR and other legislative requirements.
- Stabilise, and where required remediate the asset deterioration and specific corrosion issues to ensure that they do not result in a loss of containment of high

pressure gas, present a safety risk, and are not a limiting factor on availability or performance of the NTS.

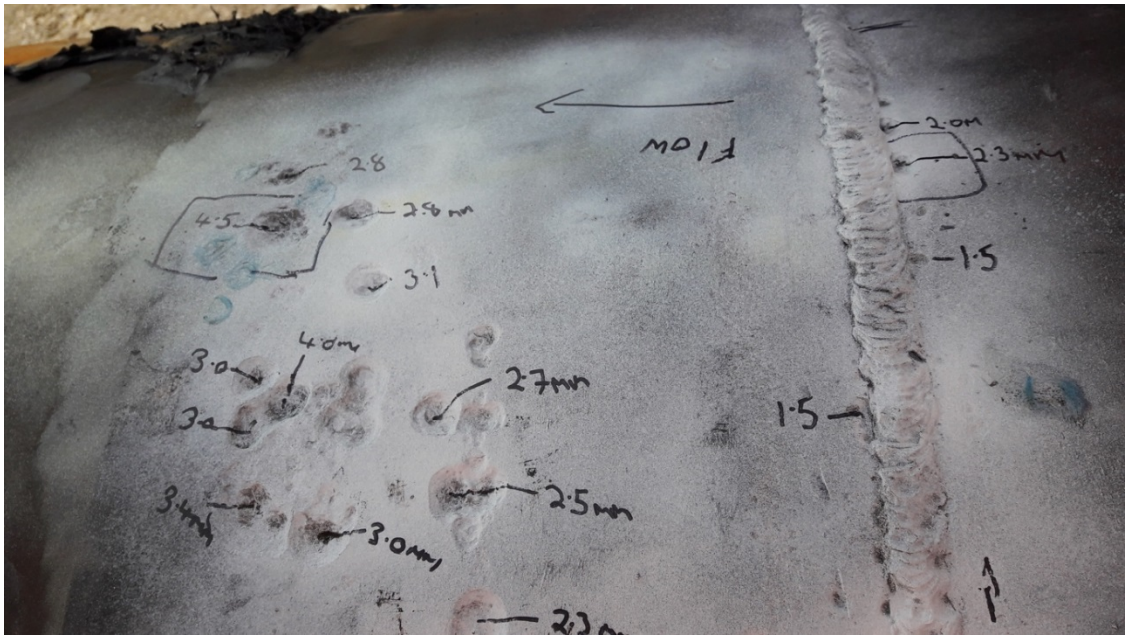
- Investigate and resolve specific areas of risk / damage to the pipeline and its associated assets.

4.40. We consider our investment plans to be successful when these outcomes are met.

Example of Problem

4.41. Example of Pipeline corrosion taken as part of an Investigation where the pipeline was excavated and the coating removed. The picture shows multiple points of corrosion caused by a breakdown of the coating system and inadequate cathodic protection. Each of the points are marked with the maximum depth of the corrosion into the pipe wall thickness which was nominally 12.7mm (measured at 13.3mm). The deepest feature at 4.5mm represents a wall thickness loss of 34%.

Example of Pipeline Corrosion



In line Inspection

4.42. An example of the results of an in-line inspection is shown in the diagram below. This shows the summary of the external metal loss corrosion defects for a pipeline.

Metal Loss features summary

Metal Loss Features

Corrosion Features (MELO-CORR):

Metal Loss Depth	Total	At Internal Pipe Wall:		
		Yes	No	N/A
60 – 100 %	None	None	None	None
40 – 59 %	1	None	1	None
20 – 39 %	48	None	48	None
10 – 19 %	80	none	80	None
1 – 9 %	52	None	52	None
Total	**181**	**none**	**181**	**None**

Non-Corrosion Features:

Metal Loss Depth	Total	At Internal Pipe Wall:		
		Yes	No	N/A
60 – 100 %	None	None	None	None
40 – 59 %	None	None	None	None
20 – 39 %	1	1	None	None
10 – 19 %	100	64	36	None
1 – 9 %	1121	823	298	None
Total	**1222**	**888**	**334**	**None**

All Metal Loss Features (MELO):

Metal Loss Depth	Total
60 – 100 %	None
40 – 59 %	1
20 – 39 %	49
10 – 19 %	180
1 – 9 %	1173
Total	**1403**

4.43. [redacted]

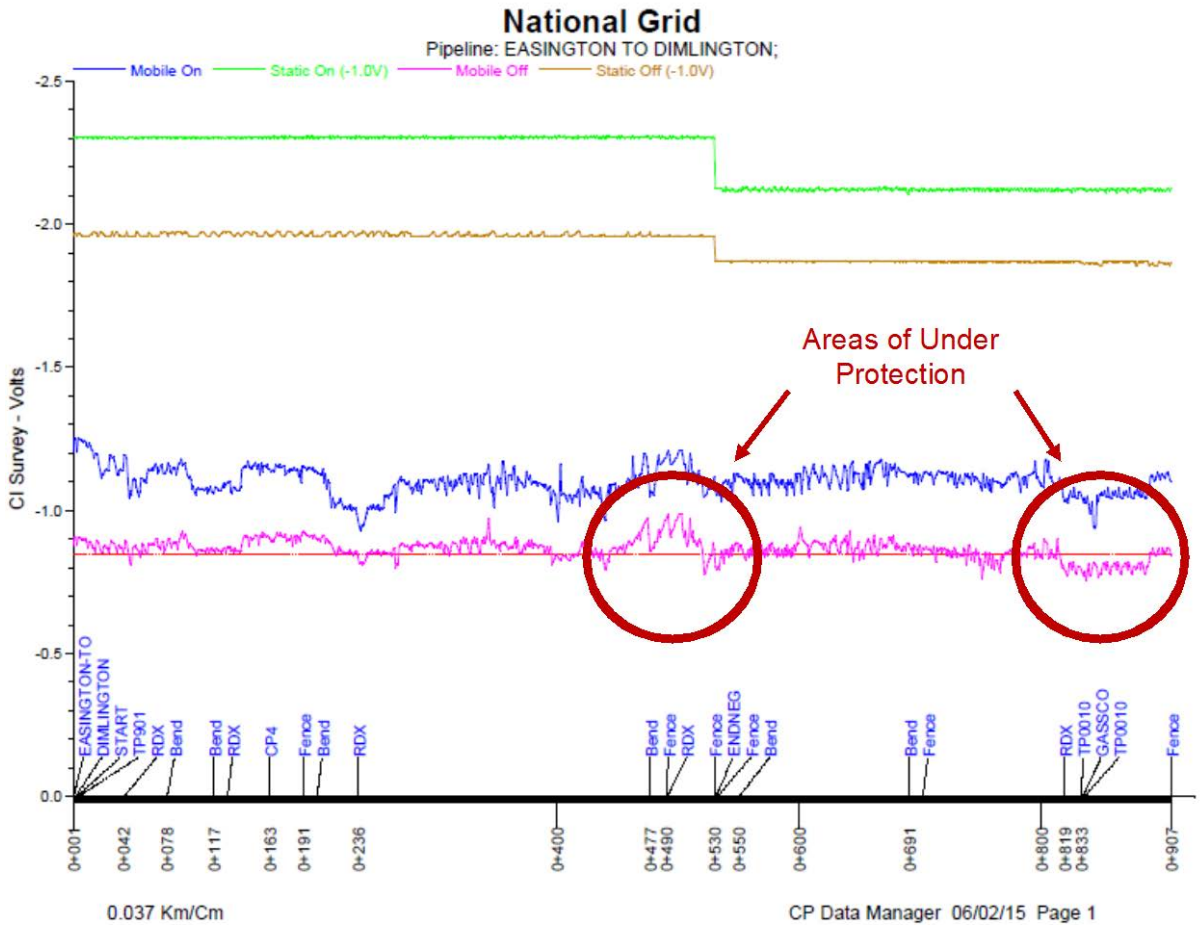
Example Feature Report

[redacted]

OLI/4 Survey

4.44. An example of the results of an OLI/4 survey are shown in the diagram below. This shows two of the key elements. The first is a CIPs showing the performance of the CP system and whether there are areas of under protection. The second is a Direct Current Voltage Gradient (DCVG) survey showing whether there are coating defects.

CIPs Chart



4.45. An example of the results of an OLI/4 survey showing the coating defects is shown in the diagram below.

DCVG Survey

ACAPS

DCVGSURVEY RESULTS SHEET

DCVG Survey

Contract No : 126-134

Survey Date : 3rd July 2013

FM21 Burton Point Spur

Anglia Cathodic Protection Services Ltd, Unit 1 Meadow View Ind Est. Reach Road, Burwell, Cambs, CB25 0GH, 01638 745599

Location	Pipeline Chainage (Km)	Section Distance in M	O.S. Grid: Easting	O.S. Grid: Northing	P/RE (mV)	OL/RE (mV)	S1 (mV)	S2 (mV)	dx (m)	D (m)	P/RE (mV)	%IR	<1%	1-15%	15-35%	35-60%	60-100%	TP On (-) mV	TP Off (-) mV	Sizing Location Easting	Sizing Location Northing
Pipeline Section																					
Start point	0	0	329655	371884	307		307	307	0	280	307							1587	1280		
Fault 1	0	2	329657	371884		30	307	307	2	280	307	10		1						329661	371885
Turn	0	18	329672	371879			307	307	18	280	307										
CP10 -1.587 on -1.280 off	0	54	329692	371909			307	307	54	280	307										
Turn	0	66	329692	371938			307	307	66	280	307										
Fault 2	0	183	329806	371914		75	307	307	183	280	307	24			1					329803	371908
Turn	0	206	329828	371908			307	307	206	280	307										
fault 3	0	261	329855	371860		12	307	307	261	280	307	4		1						329856	371864
Fault 4	0	274	329858	371847		20	307	307	274	280	307	7		1						329855	371848
End Survey	0	280	329862	371843	307		307	307	280	280	307							1587	1280		

Total 0 3 1 0 0

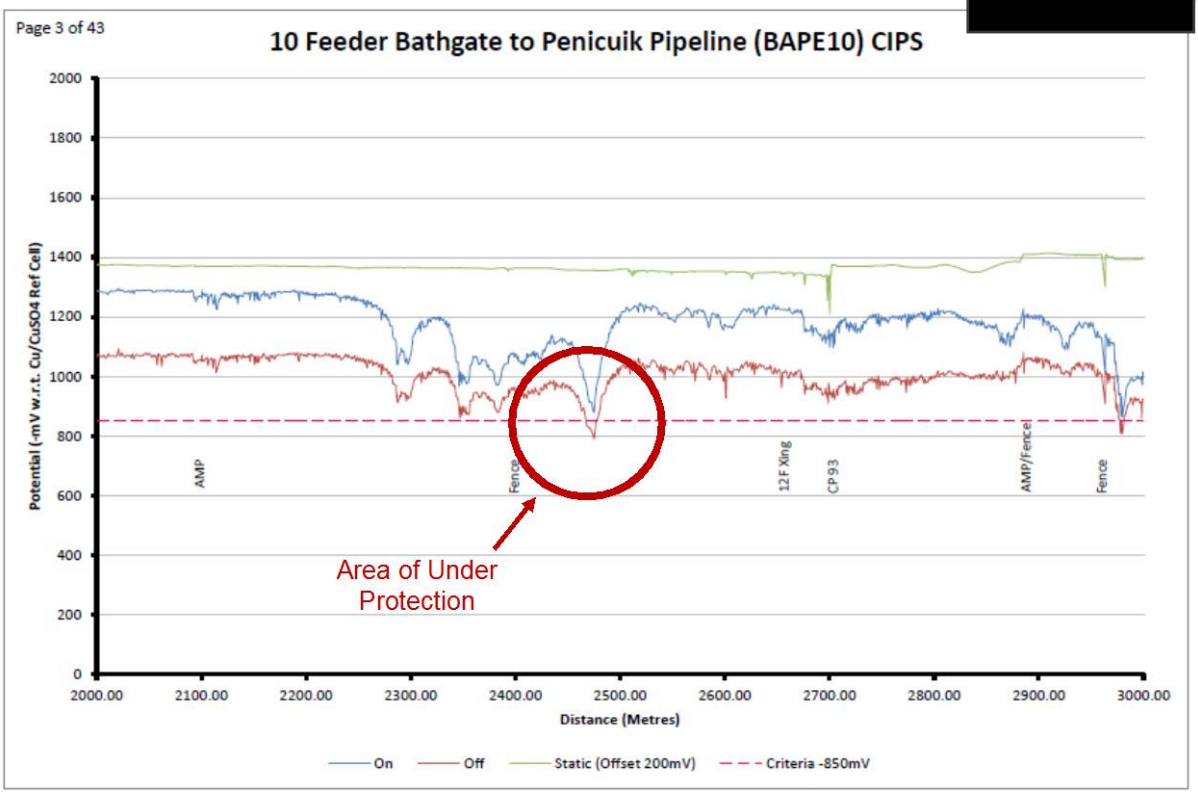
Total Number of defects 4

Coating Defect Severity

CIPS Survey

4.46. Below is an extract from a CIPs (Close Interval Potential Survey) showing the performance of the CP system and whether there are areas of under-protection

CIPs Extract



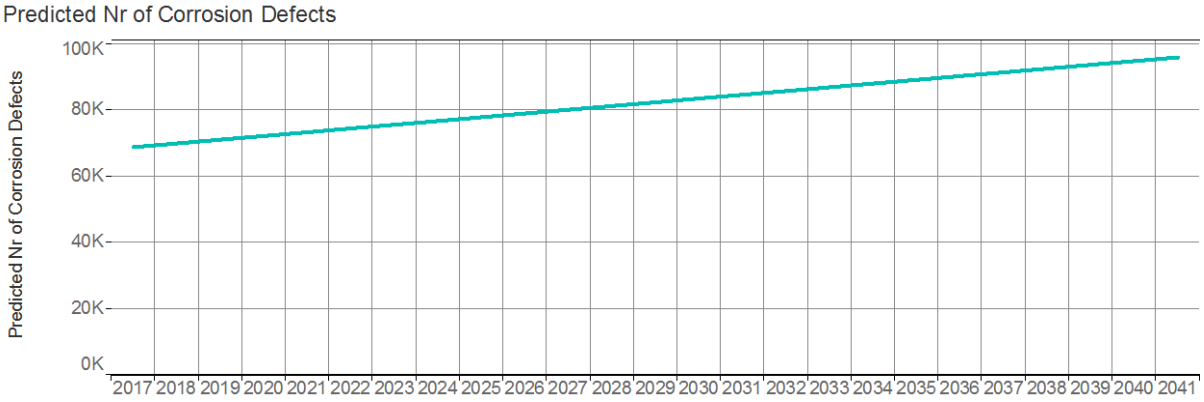
Spend Boundaries

4.47. The proposed investment includes all the buried pipeline and associated assets across the NTS. Small sections of buried pipework and the site-specific CP systems are included in the justification report for Plant and Equipment.

5. Pipeline Coating and CP System - Probability of Failure

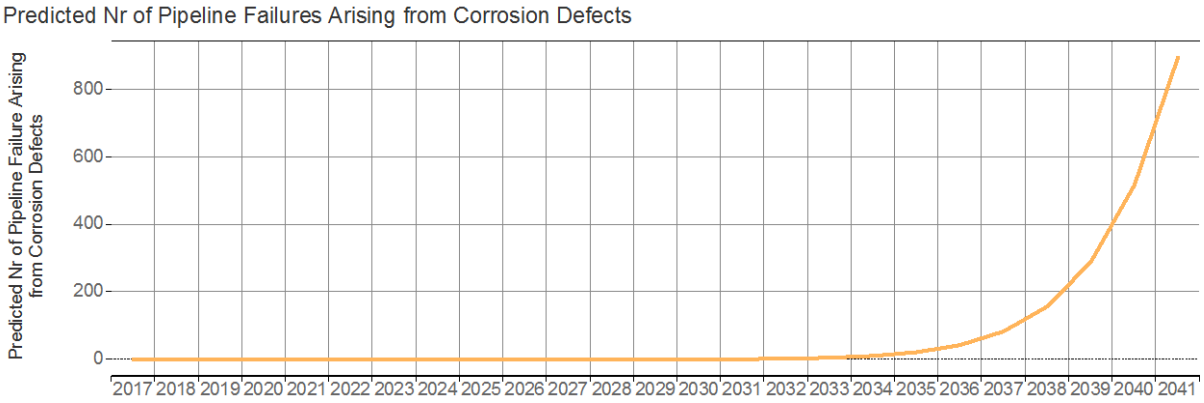
5.1. The chart below shows the predicted number of corrosion defects (features identified from ILI runs) and the expected corrosion related failures if there is no investment. The current 70,000 features are assessed and result in 6,902 current monitored external metal loss corrosions. This is based on our NOM methodology model.

Predicted Corrosion defects



5.2. The predicted number of failures rises due to lack of investment in the remediation of the CP systems and coating defects.

Predicted failures if no investment



Probability of Failure Interventions

5.3. The table below shows the drivers for Pipelines investment that are related to the current and future Probability of Failure (PoF). This includes investments that are driven by future PoF deterioration.

Drivers for Pipeline investment

NARMs Asset Intervention Categories	Secondary Asset Class
Extension of Expected Asset Life Includes Minor Refurbishments	Below Ground Pipe and Coating
Asset Refurbishment (PoF Driven) Included Major Refurbishments	Cathodic Protection
	Below Ground Pipe and Coating

5.4. These are defined as PoF-driven investments as the risk change delivered through investment is modelled as a direct consequence of replacing or refurbishing the asset. The benefits delivered through these investments will be reported as a Network Asset Risk Metric (NARM) as a reduction in monetised risk, arising from a lower PoF delivered through investment. Investment benefits vary depending on the intervention category and are consistent with the Cost Benefit Analysis (CBA) accompanying this Justification Report.

5.5. Although Cathodic Protection could be considered an indirect asset, the NOMs Methodology directly models the benefits delivered by the CP system on the pipeline it protects. It is therefore considered as a PoF-driven investment.

Consequential Interventions

5.6. All Pipeline, Coating and CP interventions are justified through a PoF driver (or through Disposal) and there are no Consequential Interventions considered.

Pipelines Interventions

5.7. The interventions for pipelines are shown in the table below:

Pipeline Interventions

Interventions	SAC	Intervention Category
A22.16.4.1 / Cathodic Protection (CIPS) Digs	Cathodic Protection	Minor Refurbishment
A22.16.4.10 / Cathodic Protection - AC mitigation	Cathodic Protection	Major Refurbishment
A22.16.4.11 / Cathodic Protection - remote monitoring	Cathodic Protection	Survey
A22.16.4.12 / Replace existing Transformer/Rectifier	Cathodic Protection	Replacement
A22.16.4.2 / Repair/Replace existing CP test posts	Cathodic Protection	Minor Refurbishment
A22.16.4.4 / In Line Inspection Defect Digs	Below Ground Pipe and Coating	Major Refurbishment
A22.16.4.5 / In Line Inspection (Pipeline PSSR Inspection)	Below Ground Pipe and Coating	Survey
A22.16.4.6 / OLI/4 (Pipeline PSSR Inspection)	Below Ground Pipe and Coating	Survey
A22.16.4.7 / OLI/4 Pipeline Defect Remediation	Below Ground Pipe and Coating	Major Refurbishment
A22.16.4.8 / CIPS for Capital Refurbishment	Cathodic Protection	Survey
A22.16.4.9 / Install new Transformer/Rectifier	Cathodic Protection	Major Refurbishment

Data Assurance

5.8. All PoF and CoF values are taken from the National Grid Gas Transmission 'Methodology for Network Output Measures' (the Methodology). The Methodology was originally submitted for public consultation in April 2018, with three generally favourable responses received in May 2018. On this basis, Ofgem were happy to provisionally not reject the Methodology pending further work to:

- Produce a detailed Validation Report, confirming the validity of data sources used in the Methodology
- Test a range of supply and demand scenarios and incorporate an appropriate scenario to best represent Availability and Reliability risk

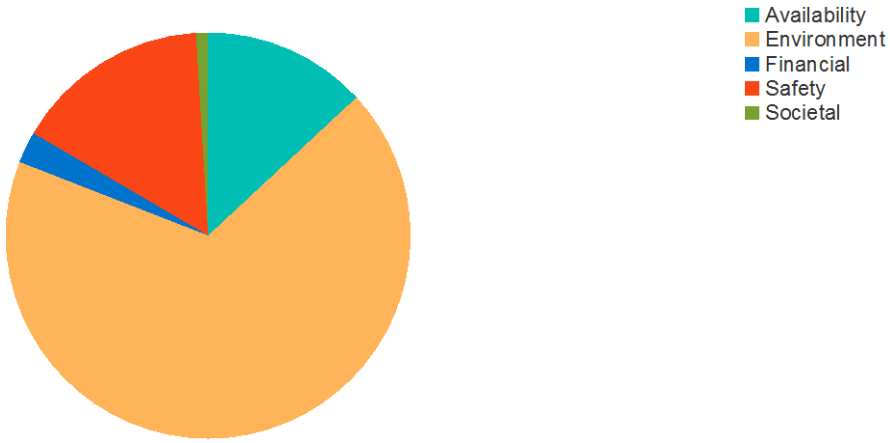
5.9. A review of the Methodology by independent gas transmission experts has been carried out and several improvements identified and incorporated.

5.10. At the time of writing, the final Validation Report has been submitted to Ofgem. We understand that once this work is complete Ofgem will formally "not reject" the Methodology and a License change progressed to restate our RIIO-1 targets in terms of monetised risk commenced.

6. Pipeline Coating and CP System - Consequence of Failure

6.1. The chart below shows the expected stakeholder impacts because of failure occurring on the pipeline assets. The charts show the relative numbers of consequence events, not relative risk.

Expected Failure Impacts



6.2. The contribution of individual service risk measures towards the overall risk for the Pipeline (including its coating protection) and associated Cathodic Protection can be explained as follows, in order of significance:

- **Environmental risk** is associated with the loss of gas arising from a leak or rupture of the pipeline caused by external interference, corrosion or other failure modes.
- **Safety risk** is associated with the potential for corrosion failure, mechanical failure, flooding, ground movement or third-party damage, causing a pipeline leak or rupture. Where the pipeline passes near centres of population the Safety risk arising from ignition of the leak or rupture is relatively large. The rate of corrosion defect growth, and hence likelihood of a leak, is strongly related by the condition of the Cathodic Protection present on the pipeline.
- **Availability risk** is associated with the potential outages associated with the shut-down of a pipeline for repair of a leak or rupture caused by external interference, corrosion or other failure modes
- **Financial risk** is mostly associated with the costs of operating and maintaining the network at the current level of risk. For Pipelines this includes costs of In-line Inspection (ILI) surveys, line walking and aerial surveillance.
- **Societal risk** is largely associated with disruption to road or rail transportation following asset failure. The likelihood of a fire or explosion is small and many assets are not near to transportation links. Therefore, the overall societal risk associated with pipeline asset failure is small.

7. Pipeline Coating and CP System - Options Considered

Potential Intervention Options

7.1. The following individual inspections and intervention categories apply to the Pipeline assets:

Inspections

7.2. **Pipeline PSSR In-Line Inspection (ILI) -** The purpose of in-line inspections is to determine the structural condition of a section of pipeline providing, an accurate description of any metal loss defects. This enables each defect to be considered and repaired where necessary. In broad terms, the inspection is to determine whether the pressure vessel (pipeline) is in an appropriate condition to meet the required duty. In-line Inspections determine metal loss due to mechanical defects, external corrosion, mechanical interference (gouges and dents), and other mechanisms.

7.3. **Pipeline PSSR OLI4 Inspection -** Ground based electrical and visual survey of the Pipeline and its environment for those Pipelines that cannot be inspected using an in-line internal inspection. Predominantly this allows an understanding of whether external interference has occurred.

7.4. **ILI Defects Investigation -** The pipeline is exposed at the point of an indicated defect from an ILI run. The purpose of this is to determine the actual size and nature of the corrosion or dents in the Pipeline to determine the remediation action to be taken. Only ILI defects that present a current threat to structural integrity or have the potential to do so before the next ILI are further investigated.

7.5. **OLI4 Defects Investigation -** The pipeline is exposed at the point of an indicated defect from an OLI4 Inspection. The purpose of this is to confirm the existence and nature of the potential defect in the Pipeline to determine the remediation action to be taken.
An expert risk-based judgement is taken to decide whether the survey results indicate an integrity threat and require this investigation.

7.6. **CP System Surveys -** Survey and assessment of the effectiveness of the CP system. The route of the CP system is manually surveyed with the performance delivered by the CP system assessed by measuring the 'electrical potential' at defined points. Due to the nature of the route of the NTS prior to the survey clearance of vegetation may be required to provide access and ensure reasonable measurements.

7.7. There are 4 types of survey undertaken at frequencies determined by the nature of the CP system being surveyed:

- Functional – The minimum number of readings at key locations to confirm that the CP system is functioning
- Interim - The minimum number of readings at a series of additional locations to a functional survey to confirm that the CP system is functioning and current flow is being achieved broadly across the system.
- Major – A series of energised "on" and polarised "off" readings at each of the test posts to understand the performance of the CP system at strategic points.

- Close Interval Potential Survey – A series of energised “on” and polarised “off” readings across the whole pipeline route to understand the performance of the CP system.

7.8. Defects identified from each of these surveys will result in varying impacts on the performance of the CP systems and the ability to protect the buried pipeline from corrosion. Equipment faults are dealt with through the normal fault remediation process. Performance issues require more detailed investigation which may require interventions ranging from CP System Enhancement through to excavation and repair of degraded coating.

Interventions

7.9. The results of an ILI, OLI4 or CP Survey could result in any of the following interventions. The decision on the intervention to be undertaken is specific to the nature and location of the defect. In the case of Pipeline defects this determines the level of residual strength in the pipeline and therefore the intervention required to ensure that the pipeline continues to be fit for purpose. The effect of types and nature of defects on the integrity of the pipeline have been developed based on historic and ongoing experimental destructive testing.

7.10. **Coating Repair -** The excavation of the pipeline and the preparation of the surface and application of an appropriate coating to reinstate the primary protection against corrosion. For below ground pipeline significant excavation is required.

7.11. **Pipeline Repair -** For the minor redressing of the pipeline and reinstatement of the coating for external corrosion of the pipeline and external interference damage. For below ground pipeline significant excavation is required.

7.12. **Pipeline Refurbishment -** For external corrosion of the pipeline and external interference damage more significant issues can be resolved by the installation of a shell or clamp over the pipeline and the reinstatement of the coating. For below ground pipeline significant excavation is required.

7.13. **Replacement of Pipeline Section -** For significant external corrosion, external interference damage or internal corrosion, a section of the pipeline can be replaced which consists of Pipeline isolation and shutdown, vent inventory, purge, cut out affected section and weld in replacement, reinstate coating and recommission. For below ground pipeline significant excavation is required.

7.14. **CP System Enhancement -** The installation of additional CP system transformer rectifiers and associated assets to return the performance of the CP system to acceptable levels.

7.15. **CP System Refurbishment -** Replacement of existing transformer rectifiers, ground beds and test posts to restore the CP system to original performance.

7.16. **CP System Remote Monitoring – Ongoing -** There is an ongoing external charge for the provision of the Rectifier and Test Post remote monitoring.

7.17. **CP System Remote Monitoring – Replacement -** Upgrade / replacement of the remote monitoring assets to enable them to continue to operate.

7.18. **AC Corrosion Investigation -** These are location specific investigations into the impacts of AC on the Pipeline. There are number of locations on the NTS where this

is a credible risk and further work is required during the investment period to further understand and mitigate.

7.19. For below ground pipework there is the option to do significant pipe replacement or coating reapplication, however this is extremely expensive. Therefore, the internal and ground based surveys combined with effective Cathodic Protection and the associated investigation and remedial work is by far lowest whole life cost/risk solution to managing the long-term health and performance of this critical asset.

7.20. A typical excavation to investigate a pipeline issue takes between 2 and 6 weeks and costs in the order of £150,000. Investigation of a corrosion defect will require a pressure reduction to reduce the stress on the pipeline prior to investigation. Due to the integrated nature of the NTS, this will normally result in a pipeline outage.

Intervention Unit Costs

7.21. The total RIIO-2 investment for Pipeline, Coating & CP represents 92% of the Pipelines investment theme. The unit costs that support the Pipeline, Coating & CP investment have been developed using a significant number of historical outturn cost data points and where this has not been possible other estimation methods have been applied. Full details of our RIIO-2 unit cost methodology can be found in the Asset Health Unit Cost Annex

7.22. 86% of costs for Pipeline, Coating & CP are supported by historical outturn information. The unit costs for ILI and CIPs digs, have been developed from outturn cost information using the 25 defect rectifications completed in the last two years. Costs for PSSR inspections have been developed from generating unit costs from the past 3 years and 33 previous inspections applied to the specific PSSR annual workload scheduled over RIIO-2. Further outturn and supplier quotation information is being gathered and is likely to latterly become available for transformer/rectifier replacement, CP remote monitoring, CP Test Post replacement and CIP survey costs.

7.23. The table below provides the unit costs for all the potential Pipeline, Coating and CP interventions.

Intervention Unit Costs – Pipeline, Coating and CP

Intervention	Cost (£)	Unit	Evidence	Data Points	Overall value in BP
Below Ground Pipe and Coating					
A22.16.4.1 / Cathodic Protection (CIPS) Digs	[redacted]	Per defect	Outturn	13	£59,290,442
A22.16.4.10 / Cathodic Protection - AC mitigation	[redacted]	Per asset	Estimated - Other	0	£1,133,611
A22.16.4.11 / Cathodic Protection - remote monitoring	[redacted]	Per asset	Estimated - Other	1	£6,704,857
A22.16.4.12 / Replace existing Transformer/Rectifier	[redacted]	Per asset	Estimated - Other	1	£1,995,155
A22.16.4.2 / Repair/Replace existing CP test posts	[redacted]	Per asset	Estimated - Other	1	£1,771,525
A22.16.4.4 / In Line Inspection Defect Digs	[redacted]	Per defect	Outturn	1	£33,291,812
A22.16.4.5 / In Line Inspection (Pipeline PSSR Inspection)	[redacted]	Per survey	Outturn	29	£18,475,629
A22.16.4.6 / OLI/4 (Pipeline PSSR Inspection)	[redacted]	Per survey	Estimated – Other	1	£157,586
A22.16.4.7 / OLI/4 Pipeline Defect Remediation	[redacted]	Per defect	Outturn	1	£2,154,273
A22.16.4.8 / CIPS for Capital Refurbishment	[redacted]	Per survey	Estimated – Other	1	£3,151,721
A22.16.4.9 / Install new Transformer/Rectifier	[redacted]	Per asset	Estimated - Other	0	£3,314,267

Innovation

7.24. During RIIO-1, we have continued to develop a dynamic portfolio of projects aligned to the Gas Network Innovation Strategy which deliver real value to our customers, stakeholders and the wider industry. We will be continuing to focus on the implementation of innovation into business as usual to drive value throughout everything we do. We will also remain committed to sharing these ideas and best practice across the wider industry to deliver a safe, reliable and efficient network that benefits gas consumers across the UK.

7.25. For pipeline, coating and CP, we developed and implemented several projects in the RIIO-1 period which will be brought forward into this investment period:

- **Artificial Intelligence for Pipe Coating Inspection**, currently in development, this project is looking to develop a smart learning tool for assessing images of corrosion in-line with CM/4. As more corrosion images are processed, the tool learns and improves its understanding, which should improve asset and corrosion management system.
- **Induction Heating**, is an installation technique which will improve the efficiency of heating pipeline for welds by using a more precise induction heating method rather than traditional blowtorch heating of pipe. This will save time and efficiency of welding, with an estimated indicative saving of £22,000 per 42” girth yield.

- **Acoustic Resonance Technology (ART),** is developing an alternative technique for use in ILI runs to give alternative data which could be used to inform future management of assets.

- **X80 Plain Dent Integrity -** Investigate integrity of plain dents in L555 (X80) grade linepipe. This study will look at the impact dents and damage have on the integrity of the X80 grade pipeline, to ensure that it is still safe and suitable for use in transporting gas. This will also reinforce the safety case for dents in X80 pipe and so should reduce the amount of future work that is done to rectify these.

- **Epoxy Grout Investigation and Analysis**, is a project which improved efficiencies of the grouting process, reducing the number of components and grades used. This gives more efficient use and reduced costs with a greater supplier base.

- **EMAT – In-line Coating Disbondment Detection Assessment**, a non-destructive technique, which has been tested for use as part of an ILI run. Currently the results are being assessed and reviewed with possible implementation at the end of RIIO-1/ start of RIIO-2.

7.26. We are also looking to continue to develop the following projects and deliver benefit from them in this investment period:

- Development of AC OHL survey system and evaluation of ER probes, this project assessed the possible impact that nearby AC cables, installed after the pipeline, could have on the installed pipeline. AC corrosion is faster acting than normal corrosive action, and so could quickly and determinately affect the pipeline, so understanding which areas are most at risk is key to managing it.

- MiniLog Stray Current Monitoring Devices for Cathodic Protection Re-Life, this is a smart and more efficient method for resolving CP defects by taking readings over 48 hrs using a remote device. This has been used 16 times to deliver £144,000 of saving by resolving 16 defects, with a saving of £9,000 per defect, however resolving a defect may lead to more work to remedy the underlying causes.

- High Frequency Pipework Vibration - a novel mitigation method for high frequency main pipework vibration. This project provided a solution for mitigating high frequency pipework vibration, which now forms part of the range of possible solutions to this type of problem. Benefit would only be seen if we used this technique as opposed to others.

- Epoxy Sleeves - in place of heavy wall pipe, this project would give the same protection benefit of a heavy wall pipe while being cheaper to install.

- Seam Weld Identification, this technique allows for improved identification of girth welds when investigating corrosions on pipelines, if the weld cannot be found when investigating corrosion action on pipelines, then corrosive action is assumed. Improved identification mitigates the need to investigate further saving an estimated £17,000 when this is avoided, with an estimated 3 investigations avoided per year.

7.27. A major innovation project for NG is project GRAID for the inspection of above ground pipeline. The application of this technology to the non-piggable sections of below ground pipeline will be investigated and implemented during the investment period.

8. Pipeline Coating and CP System - Programme Options

8.1. Our aim in developing the investment plan is to deliver value to our consumers and stakeholders. Hence, we have considered a range of options from the do nothing position through to reductions in risk. These have then been appraised as to whether they deliver consumers and stakeholders required outcomes.

8.2. As discussed – in the section on Management of the Pipeline Asset – although most of the pipeline is over 40 years old, it is external corrosion defects and damage that limits the life of the asset. Coatings are generally degrading which puts more emphasis on the performance of Cathodic Protection systems to limit defect growth. However, these systems need increasing maintenance and upgrading to meet a growing performance demand. Lack of investment will result in an unsustainable situation where the volume of corrosion defects will grow to a level where the performance on the NTS cannot be maintained and any level of remediation would not keep pace with degradation. This would place the NTS in a state where only significant asset replacement would counter the corrosion issues.

8.3. In developing our plan, we have analysed the following options which assess differing balances of investment in cathodic protection, defect investigations and pipeline inspection / remediation.

- Baseline
- Maintain Risk
- No Remediation of Cathodic Protection
- Investigate / Remediate all CIPS Defects

Baseline – Do Nothing

8.4. The impact of no investment in our Pipelines has an increase in service risk over a 10-year period, the most significant impact being a three-fold increase in the number of potential outages every year caused by pipeline asset failures and the subsequent isolation of Pipeline sections on the NTS to effect repairs. This is the option against which all the other options are compared.

Programme Option – 1 – Maintain Risk

8.5. The baseline position consists of reactive opex only, with no capex included in the baseline.

8.6. This option includes the remediation/upgrade of all CP systems and the installation of all required transformer rectifiers in new locations. It includes a balanced level of investigation and associated remediations that are targeted on the pipelines with older Coal Tar coatings that are subject to frequent In Line inspections.

Programme Option 2 – No Remediation of Cathodic Protection

8.7. This option does not include upgrade or remediation of any of the CP systems and no investigation of any of the defects identified as part of the CIPs surveys.

Programme Option 3 – Investigate / Remediate all CIPS Defects

8.8. This option includes the remediation/upgrade of all CP systems and the installation all required transformer rectifiers in new locations. It also increases the number of

investigations and associated remediations to include all of those defects identified as part of the CIPS surveys.

Programme Options Summary

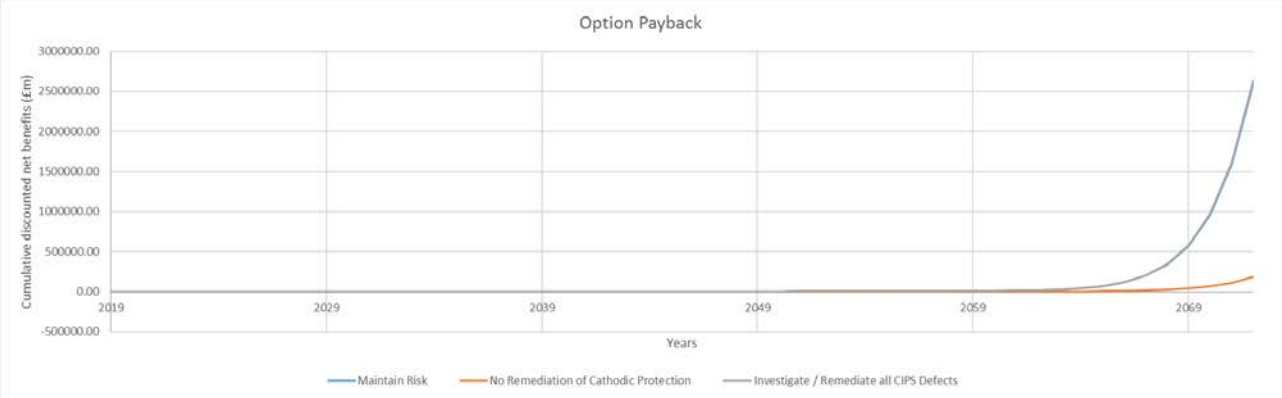
8.9. In considering the CBA for each of the programme options, a summary of all of the potential programme options is provided in the table below.

Potential Programme Options

Option	RIIO-2 Invest' £ m	RIIO-3 Invest' £ m	PV Costs £ m	PV benefits £ m	Net NPV £ m	CB Ratio	Payback Period (years)
1 – Maintain Risk	£131.44	£106.62	£287.36	£118,038.37	£117,751.01	410.77	5
2 – No CP Remediation	£71.72	£64.73	£175.79	£8,603.48	£8,427.69	48.94	7
3 - Full CIPS Investigation / Remediation	£148.09	£113.08	£306.68	£119,726.67	£119,419.98	390.39	5

8.10. The graph shows the cumulative discounted NPV of the net benefit for each of the investment options.

Option Payback – Net NPV



Programme Options Selection

8.11. All of the potential options are cost beneficial over the 45-year analysis period. The selection of the preferred option has therefore been based on an assessment of:

- the level of risk of the pipeline assets on the availability of the NTS as a whole
- whole life cost to maintain the integrity of the pipeline asset
- ensuring the continued safety of our staff and members of the public
- the overall level of investment required
- delivering value for consumers and stakeholders.

The outcomes associated with each option are provided below:

Programme Option 1 – Maintain Risk

8.12. This option manages the long-term integrity of the pipeline with remediation of the CP systems and a risk-based level of CIPS investigation / remediation that is targeted on pipelines with highest risk of defects. By managing the integrity of the pipeline, this allows continued service to our customers with low levels of safety and environmental risk.

Programme Option 2 – No Remediation of Cathodic Protection

8.13. This option does not include any remediation or improvement of the Cathodic Protection (CP) systems. Therefore this option relies on inspection and remediation of the pipeline defects when identified via In line Inspection. The severity of existing corrosion defects on the pipeline will be allowed to increase and as the coating further deteriorates, more corrosion defects will form. Increased severity of defects will increase the PSSR ILI inspection frequency which will find more defects that need to be investigated or remediated.

8.14. This option starts to put the pipeline into a cycle of decline, significantly increasing the whole life costs, and becoming unsustainable from a financial and logistical perspective in the short to medium term.

8.15. This option increases the costs for our customers and does not provide the balanced maintenance of safety, availability and environmental risk our stakeholders require.

Programme Option 3 - Investigate / Remediate all CIPS Defects

8.16. This option delivers similar outcomes to Option 1 together with further reductions in risk across all of them. However, this reduction in risk requires an increased level of investment across the period.

Preferred Option

8.17. Our preferred option is Option 1 to ensure the medium-term integrity of the pipelines, particularly through investment in CP systems. This ensures that we do not pass the point where corrosion becomes unmanaged and unrecoverable. It manages the pipelines at lowest whole life cost at an acceptable level of investment.

8.18. With no effective cathodic protection on many sections of the pipeline, Option 2 allows corrosion to increase to an unacceptable level that is likely to put the pipeline assets into an unrecoverable state of decline. This significantly increases the medium term performance and financial risk of this critical asset. From a deliverability and affordability perspective, corrosion on the pipelines asset would not be able to be remediated.

8.19. Whilst reducing the overall level of risk within the Pipelines asset through increased CIPS investigation and remediation, Option 3 also requires a significant increase in investment. There is no support for such a reduction in risk or increase in investment from stakeholders.

8.20. A complete explanation of the selected option is provided in the next section.

9. Pipeline Coating and CP System - Business Case Outline and Discussion

9.1. In this section, we set out our overall investment plan for Pipeline, Coating and the Cathodic Protection System. This section demonstrates why the proposed investment levels are the right levels to ensure the health and reliability of these assets for the investment period and beyond.

Key Business Case Drivers Description

9.2. These assets deteriorate over time and with use, which in turn leads to their inability to perform their required function. This can also result in them no longer complying with direct legislative requirements, such as PSR. Defects and damage from external parties or ground movement can further impact the integrity of the Pipeline or its Coating. In addition, there are obsolescence risks around the 3G communications network which is due to be shut down during the period 2021-2025.

9.3. Therefore, in developing our risk forecasts and proposed plans we have considered the impact of the following drivers for investment on these assets:

- Legislation
- Asset Deterioration, linked to our ageing network
- Defects
- External Interference
- Obsolescence.

9.4. Considering these drivers ensures that we develop plans that meet our legal obligations to intervene, allows us to manage external risks and obsolescence effectively, and ensures we prioritise the right assets for investment.

Business Case Summary

9.5. In appraising asset health investment, we have considered how assets can impact on several outcomes:

- Reliability risk
- Environmental risk
- Safety risk
- Societal risk.

9.6. Failures of pipelines can impact directly on these outcomes particularly the safety of members of the public who live, work and travel near our buried assets.

Outcomes Delivered

9.7. Maintaining the health of these assets is important in ensuring they continue to deliver the required network capability. Specific outcomes associated with this investment are:

- Maintaining the integrity and safety of the pipeline asset now and in the long term efficiently and effectively through the management of the coating and cathodic protection of the buried pipelines.
- Maintaining legal compliance, most notably with PSR.
- Managing and remediating asset deterioration and specific corrosion issues to ensure that they do not result in a loss of containment of high-pressure gas, present a safety risk, are not a limiting factor on availability or performance of the NTS.
- Investigating and resolving specific areas of risk / damage to the pipeline and its associated assets.

9.8. Our proposed investment will ensure that we maintain our low levels of risk across all these outcomes.

Stakeholder Support

9.9. Consumer and stakeholder research and engagement has been integral to the development of our asset health investment plans. Early discussions realised that to engage in meaningful dialogue, our plan outputs should be presented at a programme rather than asset level of detail. This is due to the integrated nature of our Asset Health plan which makes it challenging to disaggregate and engage on individual elements. For details of our stakeholder engagement approach please refer to 'I want to take gas on and off the system where and when I want' [Chapter 14 of the GT submission].

Investment Decision Approach

9.10. To deliver the outcomes for the investment period these assets require the right mixture of the intervention categories (defined in above) to deliver acceptable and affordable outcomes for our stakeholders.

9.11. The decision on the volume of each of the interventions required on the Pipeline, Coating and CP assets has been undertaken through a combination of:

- **Pipeline PSSR In-Line Inspection (ILI)** – these are undertaken at flexible intervals (Up to a maximum of 15 years) based on the performance and condition of the pipeline and associated assets.
- **Pipeline PSSR OLI4 Inspection** - these are a time-based intervention (every 5 years) calculated from the last inspection date for all applicable assets.
- **CP System Surveys** – the functional, interim and major inspections these are a time-based intervention calculated from the last inspection date for all applicable assets. The Close Interval Protection Survey is linked to the frequency of the ILI runs and its undertaken at minimum every 10 years as close as possible to the midpoint between ILI runs.
- **ILI Defects Investigation, OLI4 Defects Investigation, Coating Repair, Pipeline Repair, Pipeline Refurbishment, Pipeline Replacement** - the volume of these has been predicted based on known issues and historical frequencies combined with a risk based assessment of those pipelines that will be subject to the most significant and fastest corrosion growth.

- **CP System Enhancement and Refurbishment** - results of the CIPS Surveys have been analysed and used to identify the location and type of enhancement that is required for each individual CP system.
- **CP System Remote Monitoring – Ongoing and Replacement** – remote monitoring is the lowest whole life cost for undertaking regular functional inspections for the CP systems. The existing service contract for their operation will be maintained. Replacement of the CP remote monitoring systems will be undertaken when the existing 3G system is decommissioned
- **AC Corrosion Investigation** – the issue of AC corrosion needs to be investigated during the period, the number and type of locations to undertake this have been determined to provide a sample of results that will allow robust analysis of the issue.

9.12. The investment proposed in the period is to:

- Undertake the ILI and OLI/4 inspection of the pipeline assets to ensure legal compliance and inform our inspections and remediation strategy
- Continue to utilise the Intervals 2 tools to manage our risk-based response to the defects and its impact on future inspections frequencies
- Undertake risk-based remediation activities targeted on the highest risk pipeline assets. An example of this is where we are seeing under protection by cathodic protection on the population of older pipelines coated with coal tar enamel, and already showing corrosion features through internal inspection.
- Remediate the defects and underperformance on the existing CP systems together with installation new CP systems where required to provide coverage of the pipelines assets. This is essential in maintaining the lowest whole life cost of managing pipeline corrosion.

Benefits of Investment

CP System Effectiveness

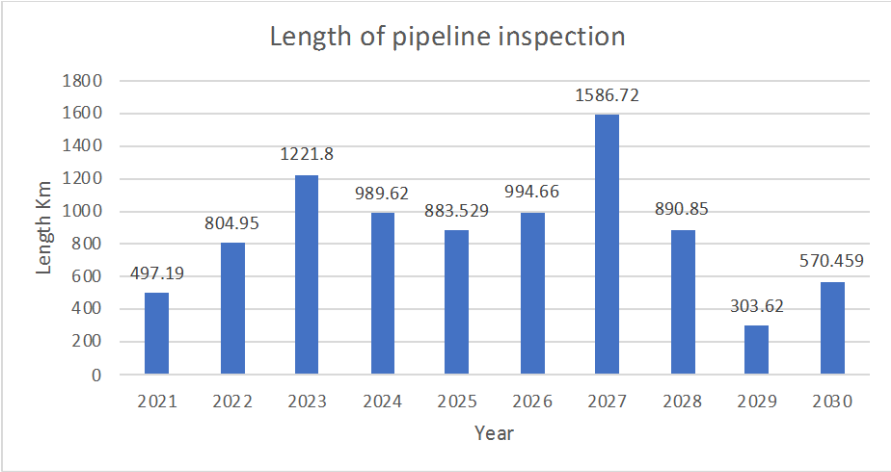
9.13. By the end of the RIIO-3 we are targeting 90% of the NTS to be protected by effective CP systems. This will be through the remediation/upgrade of all 212 CP systems and the installation 120 transformer rectifiers in new locations.

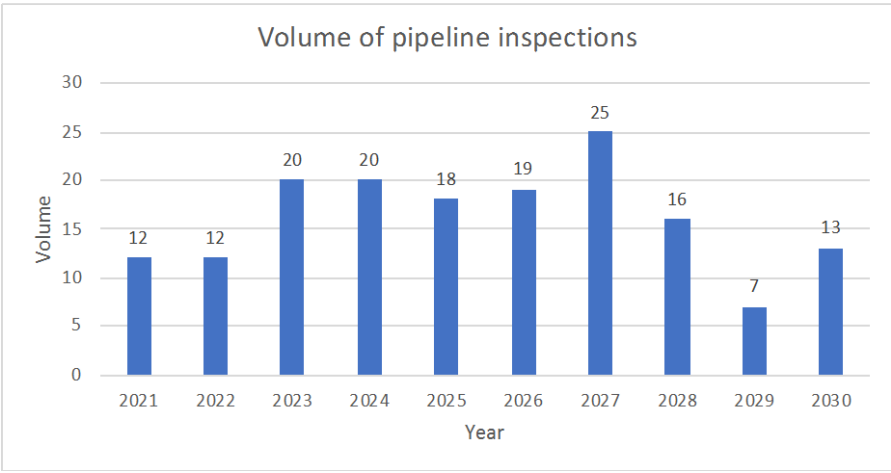
In-line Inspections

9.14. The CP system improvements and defects will decrease the overall frequency of ILI runs on the NTS from the no investment average of 9.7 years to an average of 13 years.

9.15. The charts below show the number and length of pipelines forecast to be inspected for the investment period.

Forecast Of Inspection – Length And Volume





Preferred option

[redacted]To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the pipeline, coating and CP assets in the investment period. [redacted]

Volumes for each Intervention

[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		

Asset Health Spend Profile

9.17. The profile of investment in the pipeline, coating and CP assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

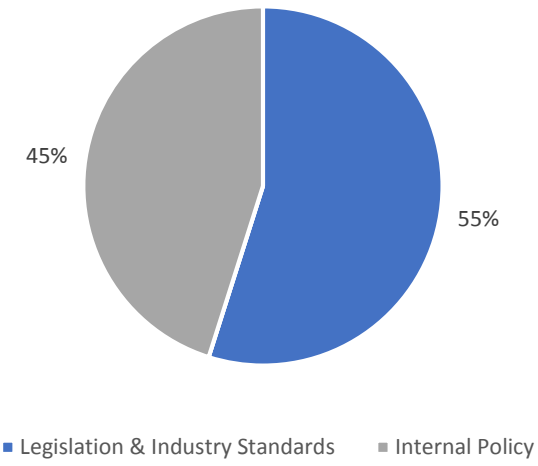
Investment Profile

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Cathodic Protection	6,703	15,665	20,333	16,705	17,955	14,482	14,038	10,044	9,355	9,332
Below Ground Pipe and Coating	11,608	9,695	9,342	11,440	11,993	9,008	10,653	8,613	9,122	11,971
Total	18,311	25,360	29,675	28,146	29,949	23,490	24,691	18,657	18,478	21,304
	131,441					**106,619**				

Intervention Drivers

9.18. The following chart shows the breakdown of investment across each of the intervention drivers. This shows that the majority of the investment consists of interventions that are driven by legislation and based on industry standards, the remainder is based on Internal Policy.

RIIO-2 Pipeline, Coating and CP Intervention Drivers[1]



Preferred Programme CBA

9.19. We are targeting an appropriate level of asset health investment to mitigate the reliability, safety and environmental risks from an ageing asset base that is subject to external pressures.

9.20. In line with HM Treasury Green Book advice and Ofgem guidance we have appraised whether investment in pipelines is value for money. We have considered costs over a 45-year period in a full cost benefit analysis (CBA).

[1] See Appendix A for intervention driver category definitions

9.21. The CBA for the pipeline investment over the period is cost beneficial over the 45-year period. This investment pays back in less than 10 years, and over 45 years is significantly cost beneficial. This is shown below.

Summary of Cost Benefit Analysis[2]

	10 years	20 years	30 years	45 years
Present Value costs (£m)	£89.13	£148.58	£210.15	£287.36
Present Value H&S benefits (£m)	£24.53	£105.19	£300.35	£16,463.77
Present Value non H&S benefits (£m)	£248.76	£1,514.53	£4,929.96	£101,574.60
Net Present Value (£m)	£184.16	£1,471.13	£5,020.15	£117,751.01

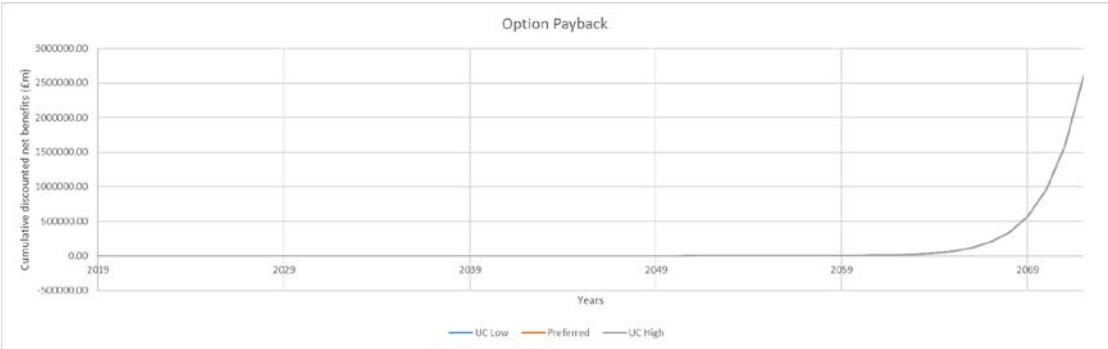
9.22. The level of risk reduction resulting from the investment is due to the significant and direct impact the pipelines have on all of our key outcomes, particularly safety. We have developed our preferred programme based on our detailed understanding of the management of the pipeline asset base and an appropriate level of risk of failure. Our investment programme ensures the medium-term integrity of the pipelines and particularly through investment in CP systems ensures that we do not pass the point where corrosion becomes unmanaged and unrecoverable. The investment manages the pipelines at lowest whole life cost avoiding the need for wholesale pipe replacement.

9.23. Our consumers have confirmed that unavailability of service is unacceptable to them and that the gas network is required to support their operations in the medium term. They and our other stakeholders, including the [redacted] have also made very clear our obligations to manage the potential safety impacts of our assets. Our proposed investment in the pipelines supports these views.

9.24. We have challenged whether this is the right programme of work. Through our asset management processes, we have assessed whether our plans are the best mix of interventions for our stakeholders and consumers.

9.25. We have used the potential range of unit cost variance to assess the sensitivity of the Cost Benefit Analysis to the upper and lower limits. Whilst the level of cost benefit and the payback period changes as the unit costs vary, the investment remains cost beneficial across the range of unit costs.

Net Benefits of Upper and Lower Unit Cost Sensitivity



9.26. We consider this level of investment to be essential to ensure we manage asset deterioration, defects, external interference and obsolescence, whilst meeting our legal

[2] A14.17.4 Pipeline, Coating and CP CBA

obligations. It will ensure we deliver the outcomes that consumers and stakeholder tell us they want us to meet.

10. Pipeline Coating and CP System - Preferred Option Scope

10.1. The section summarises our preferred investment plan required to deliver acceptable and affordable outcomes for our stakeholders.

Preferred option

10.2. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the pipeline, coating and CP assets in the investment period. [redacted]:

Volumes for each Intervention

[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		

Asset Health Spend Profile

10.3. The profile of investment in the pipeline, coating and CP assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

Investment Profile

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Cathodic Protection	6,703	15,665	20,333	16,705	17,955	14,482	14,038	10,044	9,355	9,332
Below Ground Pipe and Coating	11,608	9,695	9,342	11,440	11,993	9,008	10,653	8,613	9,122	11,971
Total	18,311	25,360	29,675	28,146	29,949	23,490	24,691	18,657	18,478	21,304
	131,441					**106,619**				

Delivery

10.4. At this point in time the delivery of our RIIO-2 and RIIO-3 plans are in principle deliverable based on initial assessments of work. We will regularly review the plan to consider any known or changing constraints, customer impacts and bundling opportunities. In the event of churn our plan must be reoptimised to reflect the impact of the change, and provide an opportunity to reconsider the efficient timing of delivery.

10.5. We recognise that many of our asset classes are co-located across the NTS pipe network and sites. Much of our investment delivery also requires outages of the

associated pipelines or plant and equipment. The availability of outages is extremely limited across most of the NTS due to the radial nature of the network. It is therefore most efficient from both financial and network risk points of view to bundle investment across asset classes within the same outage period and this may involve taking an outage on a large section of pipework and working on multiple assets/workfaces simultaneously. To achieve this, the assets need to be isolated, vented, repaired/replaced and then returned to service for the duration of their technical lives without further intervention a period which could be in the region of 25 years. The cost of recompression for a large section of the network is estimated to be in the region of £0.25m. A systematic approach therefore maximises the work undertaken in any outage whilst ensuring efficient delivery through minimised project overheads.

10.6. This approach is particularly effective when applied at a feeder level or for a whole site. In which case the preparatory inspection, investigation, risk assessment, planning and procurement activities can be completed as far as possible before the outage. This allows the maximum amount of intervention and risk reduction to be bundled into a single 'campaign' across the length of the feeder. During RIIO-1 this has proved to be an extremely efficient and effective approach to delivery of our programmes of work.

10.7. We recognise that whilst this is in many cases the most efficient method of delivery there are still individual or groups of assets that present a risk to our performance that do not 'fit' into the planned 'campaign' approach. We will ensure that these risks are remediated as efficiently as possible through individual or small groups of targeted interventions.

10.8. A small number of locations on the network require an alternative solution to the usual outage approach to mitigate the risk of disruption to customer supply. This could be for example due to customers on single network spurs. While it may be possible in some cases to negotiate commercial solutions to this, costs per day are expected to be significant and it is likely that an alternative asset solution will be required in the form of stopples (bypasses). We will seek to identify alternative more efficient solutions with our delivery units and suppliers as the nature of the interventions on each site becomes clearer through our survey work.

10.9. Where asset interventions do not require outages then the campaign approach will still be applied to maximise the opportunity for delivery of the same type of work across many locations. This enables efficient procurement through significant volumes of common works.

PIG Traps (£4.3m)

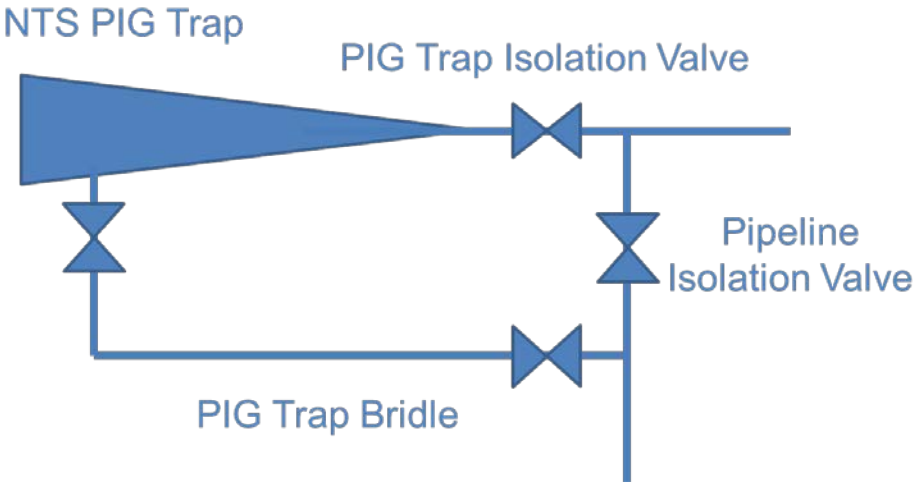
11. PIG Traps - Equipment Summary

11.1. The purpose of the PIG traps is to enable the In-line Inspections of below ground pipeline without the need for an outage of the pipeline. PIG Traps allow a series of In-line Inspection tools to be loaded, launched, received and retrieved from NTS high pressure gas pipelines. The PIG Trap and associated bridle pipework also provide a bypass arrangement to enable valve maintenance (valve closure) to take place on the pipeline isolation valve without interrupting gas supplies.

11.2. The 7,641km of pipelines that can be internally inspected comprise of 154 discrete pipeline sections, each with either a permanent PIG Trap or provision for a temporary PIG Trap at each end.

11.3. A typical NTS PIG Trap arrangement would consist of the physical trap enclosure, bridle/bypass pipework and appropriate supporting structures. They are installed and sized appropriately to allow In-line Inspection of NTS pipelines, currently ranging from 6" to 48" diameter.

NTS PIG Trap Arrangement

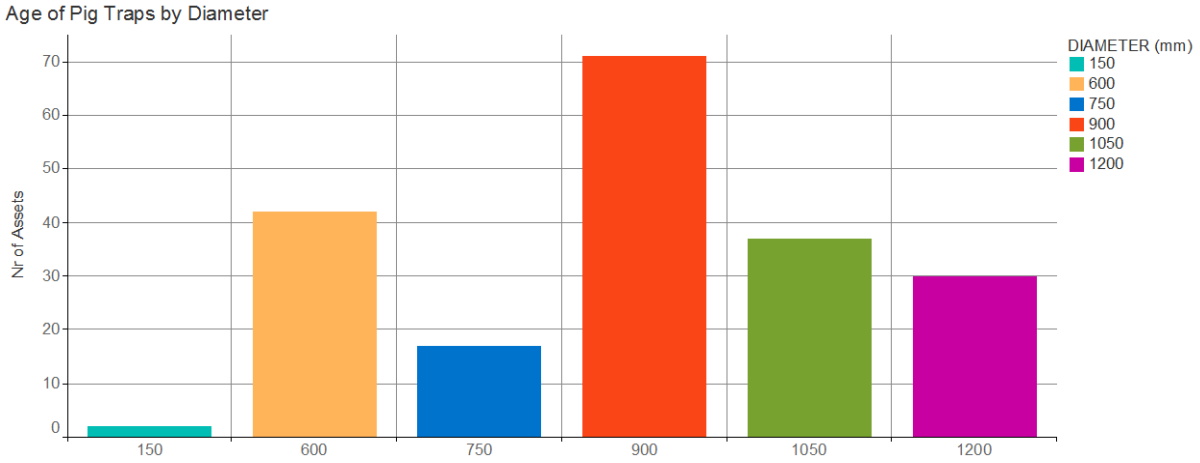


Location and Volume

11.4. There are 199 PIG traps permanently installed on sites across the NTS. There are also 109 temporary PIG traps connection points where a portable PIG trap can be transported to site and installed.

11.5. The chart below shows the number of the PIG traps split by diameter.

Number of PIG Traps by diameter



Pressure Ratings

11.6. The PIG Traps are connected to the Pipelines of the NTS and therefore operate at the full pressure of 70 to 94 bar.

12. PIG Traps - Problem Statement

12.1. PIG traps are an ageing asset that suffers from corrosion and wear related deterioration. They require ongoing inspections to maintain PSSR compliance. In our experience, ongoing defects on the PIG traps which remain unresolved can lead to non-compliance with legislation, and potential safety and environmental damage.

12.2. PIG traps allow a door to be opened onto the live pipeline and their integrity together with that of the PIG Trap isolation valve must be assured to manage the inherent risks to operators. PIG traps also suffer many more pressure cycles and tend to be prone to external and internal corrosion (esp. seal rings). A major release from an open PIG trap would be potentially challenging to contain and resolve.

12.3. Any non-compliant PIG traps would not be able to be used and this would negatively impact the ability to inspect the pipeline, with inspections only being able to be undertaken with the pipeline isolated. This would increase the costs of inspections together with the availability and resilience of the NTS.

Drivers for Investment

12.4. The key drivers for investment in the PIG Trap assets are:

- Legislation
- Asset Deterioration.

12.5. In addition to the legal requirements of PSSR the assets deteriorate over time and with use which leads to their inability to perform their required function. This can also result in them no longer complying with direct legislative requirements such as PSR.

12.6. **Legislation** – a PIG Trap is defined as a pressure vessel under PSSR. Therefore, compliance with PSSR drives regular inspection and re-validation to allow continued operation of the asset. Remediation of any issues found during inspection is also required.

12.7. **Asset Deterioration** – PIG Trap assets are above ground and subject to time-based deterioration, wear for use and fatigue from pressure changes. The coating of the PIG trap is subject to deterioration and damage from plant and machinery. Corrosion of the metal of the all parts of the asset occurs both externally and internally. The moving parts/components such as door hinges, seals and bleeder block suffer use-based wear. The pressurised elements of the asset can exhibit cracking due to fatigue.

Impact of No Investment

12.8. In appraising asset health investment, we have considered how assets can impact on several outcomes:

- Reliability risk
- Environmental risk
- Safety risk
- Societal risk.

12.9. A critical part of our appraisal method is to assess is the baseline position. This is the position where we do not invest proactively in our asset base (i.e. we fix on fail), ensuring any reactive investment meets all health and safety requirements. This is a baseline against which the incremental investment is compared to the incremental benefits. This is critical for developing value for money business plans.

12.10. In developing our baseline, we have used the same probability of failure and probability of consequence estimates, and forward-looking predictive assessment as used in developing proposed options for investment.

12.11. The baseline position does not align with our desired outcomes which are to:

- Comply with PSSR and other legislation
- Ensure any PIG Traps not economically viable to be refurbished will be replaced or removed to enable a portable PIG Trap to be used
- Manage the asset deterioration issues to ensure that they do not compromise the ability to undertake internal inspections of the Pipeline. This means ensuring that they do not result in a loss of containment of high-pressure gas, present a safety risk and are not a limiting factor on availability or performance of the NTS.

12.12. Under the baseline position, our analyses show that the use of PIG traps without investment in inspection, revalidation and remediation will breach legal obligations under PSSR. During the investment period 171 PIG traps would become non-compliant with PSSR legislation. These would need to be depressurised and are therefore unable to be used to launch ILI inspection equipment.

12.13. Lack of investment in the remediation of failures found during inspections will also render the PIG Traps unusable as their deterioration reaches the point at which they are unable to be operated effectively or at all. It is predicted that with no investment there will be 89 PIG traps with outstanding PSSR failures or significant defects by the end of the investment period.

12.14. The inability to use PIG Traps would impact on the ability and cost to undertake internal Pipeline inspections. For those sites where portable PIG traps cannot be used due to pipeline size, operational, site or access restrictions then inspections would not be able to be undertaken without incurring an outage on the NTS with all the associated operational constraints and gas venting. It is highly likely that the outages needed to maintain the ILI frequency required to manage pipeline corrosion would not be able to be maintained.

12.15. Lack of investment in PIG Traps may also lead to the loss of containment of high-pressure gas, safety related issues and environmental damage.

12.16. PSSR inspections show that 52% of inspections have resulted in the identification of defects. There are corrosion/mechanical damage related defects on 13% (or 16) PIG traps. With no investment, the number of defects will rise

12.17. We have discussed with our stakeholders a range of options around asset health. Stakeholders are clear that they do not want to see any reduction in the level of reliability and would welcome continual improvements. Hence the increase in risk under the ‘Do Nothing’ position is unacceptable to our consumers and stakeholders, who have consistently told us safety and reliability are high priorities for them.

12.18. Overall, we can conclude that the baseline position does not support stakeholders and consumer's priorities to maintain or improve safety and reliability risk across all our assets.

Spend Boundaries

12.19. The proposed investment includes all fixed PIG Traps on the NTS, including all of their subcomponents. The subcomponents that are covered under this plan include the body/door, the PIG alert and the bridle pipework.

13. PIG Traps - Probability of Failure

13.1. The probability of failure for PIG Traps is modelled using our NOMs methodology. The failure modes that contribute most to the probability of failure are:

- corrosion with no leak
- failure of the door seal.

Probability of Failure Interventions

13.2. The table below shows the drivers for Pipelines investment that are related to the current and future Probability of Failure (PoF). This includes investments that are driven by future PoF deterioration.

Drivers for Pipeline Investment

NARMs Asset Intervention Categories	Secondary Asset Class
Extension of Expected Asset Life Includes Minor Refurbishments	Pig Trap

13.3. These are defined as PoF-driven investments as the risk change delivered through investment is modelled as a direct consequence of replacing or refurbishing the asset. The benefits delivered through these investments will be reported as a Network Asset Risk Metric (NARM) as a reduction in monetised risk, arising from a lower PoF delivered through investment. Investment benefits vary depending on the intervention categories and are consistent with the Cost Benefit Analysis (CBA) accompanying this Justification Report.

Consequential Interventions

13.4. All PIG trap interventions are justified through a PoF driver (or through Disposal) and there are no Consequential Interventions considered.

PIG Trap Interventions

13.5. The interventions for PIG traps are shown in the table below:

PIG Trap Interventions

Interventions	SAC	Intervention Categories
A22.16.3.1 / Pig Trap PSSR Defect Resolution - Minor	Pig Trap	Minor Refurbishment
A22.16.3.2 / Pig Trap PSSR Major Inspection	Pig Trap	Major Refurbishment
A22.16.3.3 / Pig Trap PSSR Defect Resolution - Major	Pig Trap	Major Refurbishment

Data Assurance

13.6. All PoF and CoF values are taken from the National Grid Gas Transmission 'Methodology for Network Output Measures' (the Methodology). The Methodology was originally submitted for public consultation in April 2018, with three generally favourable

responses received in May 2018. On this basis, Ofgem were happy to provisionally not reject the Methodology pending further work to:

- Produce a detailed Validation Report, confirming the validity of data sources used in the Methodology
- Test a range of supply and demand scenarios and incorporate an appropriate scenario to best represent Availability and Reliability risk.

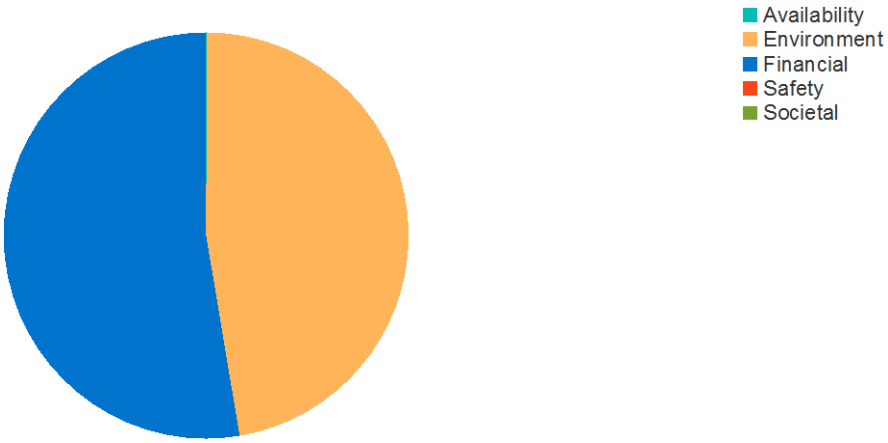
13.7. A review of the Methodology by independent gas transmission experts has been carried out and several improvements identified and incorporated.

13.8. At the time of writing, the final Validation Report has been submitted to Ofgem. We understand that once this work is complete Ofgem will formally “not reject” the Methodology and a License change progressed to restate our RIIO-1 targets in terms of monetised risk commenced.

14. PIG Traps - Consequence of Failure

14.1. The chart below indicates the expected stakeholder impacts should any failures occur on pig traps. The charts show the relative numbers of consequence events, not relative monetised risk.

Expected Stakeholder Impacts – Pig Trap Failure



14.2. The contribution of individual service risk measures towards the overall risk for Pig Traps can be explained as follows, in order of significance:

- Financial risk is associated with the costs of operating and maintaining the network at the current level of risk. For Pig Traps this is mostly associated with the cost of PSSR surveys and associated minor defects correction
- Environmental risk is associated with the loss of gas arising from leaks from a pressurised system (e.g. loss of seal)

14.3. The risk associated with other service risk measures for Pig Traps is negligible, based on the assigned failure modes.

15. PIG Traps - Options Considered

15.1. In this section, we outline the options we have considered.

Potential Intervention Options

15.2. The following individual inspections and interventions apply to the PIG Trap assets:

- **6 Yearly Inspection – Visual -** visual inspection of the PIG Trap including coating and components.
- **12 Yearly Inspection – Major -** in addition to the elements of the visual inspection, the coating is removed during the major inspection to allow a detailed examination of the pressure vessel body and welds.
- **Refurbishment** – for external corrosion or cracking issues minor redressing of the PIG Trap and reinstatement of the coating.
- **Partial Replacement –** replacement of elements of the PIG Trap such as bridle pipework and the door closure mechanism. This intervention is used when the element of the PIG trap is the only failing part of the system and is impacting its overall performance.
- **Replacement -** removal of the existing PIG trap and replace with a new PIG trap. This intervention is considered on whole life cost grounds when the ongoing cost of refurbishment and repair is greater than the cost of replacement. This is used only when the PIG trap is 36' diameter and above or when the site conditions, such as access, mean that the portable PIG Trap cannot be used.
- **Removal -** removal of the existing PIG trap and replace with connections for temporary pig trap installation and suitable bypass pipe-work for ongoing valve operations. This intervention is considered on whole life cost grounds when the ongoing cost of refurbishment and repair is greater than the cost of removal. This is used only when the PIG trap is less than 36' diameter and when the site conditions, such as access, mean that the portable PIG Trap can be used. Removing the pig trap removes the requirement for inspection and maintenance it also removes the potential hazard of the door closure by replacing it with a blank flange or contiguous pipework which is a more secure point of containment.

Intervention Unit Costs

15.3. The total RIIO-2 investment for the PIG Traps represents 3% of the Pipelines investment theme. The unit costs that support the PIG Traps investment have been developed using historical outturn cost data points.

15.4. Major defect resolution is based on outturn costs and minor defect resolution has been estimated by other means. In both instances, further data gathering is taking place to extract outturn data from the works PMC has performed over the last 5 years. This will be available and used to update and substantiate unit costs following this submission.

15.5. All PSSR major inspection works are delivered 'in-house' by PMC and the unit costs have been developed from the past 6 years of outturn project information consisting of multiple data points.

15.6. The table below provides the unit costs for all interventions for PIG Traps.

Unit Costs for Interventions – PIG Traps

Intervention	Cost (£)	Unit	Evidence	Data Points	Overall value in BP
PIG Traps					
A22.16.3.2 / Pig Trap PSSR Major Inspection	[redacted]	Per asset	Outturn	1	£ 2,514,556
A22.16.3.1 / Pig Trap PSSR Defect Resolution - Minor	[redacted]	Per asset	Estimated - Other	1	£ 710,991
A22.16.3.3 / Pig Trap PSSR Defect Resolution - Major	[redacted]	Per asset	Outturn	7	£ 1,042,366

Innovation

15.7. During RIIO-1, we have continued to develop a dynamic portfolio of projects aligned to the Gas Network Innovation Strategy which deliver real value to our customers, stakeholders and the wider industry. We will be continuing to focus on the implementation of NPV into business as usual to drive value throughout everything we do. We will also remain committed to sharing these ideas and best practice across the wider industry to deliver a safe, reliable and efficient network that benefits gas consumers across the UK.

15.8. For PIG Traps, we are looking to continue to develop the following project and deliver benefit from them in this investment period:

15.9. Pig Trap Door Seals - by delivering a novel training course giving a greater understanding of the maintenance requirements of PIG trap door seals, which has meant that previous failures have been avoided which has saved an estimated £10,000 per year and looks to deliver the same benefit into and through the investment period. This saving comes from the cost of avoiding having to repair the seals.

16. PIG Traps - Programme Options

16.1. Our aim in developing the investment plan is to deliver value to our consumers and stakeholders.

16.2. As described in the section below 'PIG Traps - Business Case Outline and Discussion – Investment Decision Approach' our investment in PIG Traps is driven from the results of mandatory PSSR inspections. If defects are identified at the time of inspection then the lowest whole life cost intervention that meets the technical requirements and legal obligations is implemented.

16.3. The proposed programme is based on the best available information and represents the lowest whole life programme of investment over RIIO-2 and RIIO-3. The proposed investment is the "do minimum" option to maintain compliance.

16.4. Whilst further options could be considered, due to the nature of these assets and the simplicity of the interventions to be done, it is not prudent or affordable to consider options which would add unnecessary cost to the plan. We have therefore not considered any further programme options as any of those would be an increase in initial investment and overall whole life cost from this proposed position.

17. PIG Traps - Business Case Outline and Discussion

17.1. In this section, we set out our overall investment plan for PIG Traps. This section demonstrates why the proposed investment levels are the right levels to ensure the health and reliability of these assets for the investment period and beyond.

Key Business Case Drivers Description

17.2. In addition to the legal requirements of PSSR, the assets deteriorate over time and with use, which leads to their inability to perform their required function. This can also result in them no longer complying with direct legislative requirements such as PSR.

17.3. Therefore, in developing our risk forecasts and proposed plans we have considered the impact of the following drivers for investment in the PIG Trap assets are:

- Legislation
- Asset Deterioration.

17.4. Considering these drivers ensures that we develop plans that meet our legal obligations to intervene and prioritise the right assets for investment.

Business Case Summary

17.5. In appraising asset health investment, we have considered how assets can impact on several outcomes:

- Reliability risk
- Environmental risk
- Safety risk
- Societal risk.

17.6. Failures of PIG Traps can impact on all of these outcomes.

Desired Outcomes

17.7. Maintaining the health of these assets is important in ensuring they continue to deliver the required network capability. Specific outcomes associated with this investment are:

- We will continue to comply with PSSR and other legislation
- We will manage the asset deterioration issues to ensure that they do not compromise the ability to undertake internal inspections of the Pipeline. This means ensuring that they do not result in a loss of containment of high-pressure gas, present a safety risk and are not a limiting factor on availability or performance of the NTS.
- Any PIG Traps that are not economically viable to be refurbished will have been replaced or removed to enable a portable PIG Trap to be used

Stakeholder Support

17.8. Consumer and stakeholder research and engagement has been integral to the development of our asset health investment plans. Early discussions realised that to engage in meaningful dialogue, our plan outputs should be presented at a programme rather than asset level of detail. This is due to the integrated nature of our Asset Health plan which makes it challenging to disaggregate and engage on individual elements. For details of our stakeholder engagement approach please refer to 'I want to take gas on and off the system where and when I want' Chapter of the GT submission.

Investment Decision Approach

17.9. To deliver the outcomes for the investment period the PIG Trap assets requires the right mixture of the intervention categories. The decision on the volume of each of the interventions required on the PIG Trap assets during the investment period is driven by:

- Mandatory 6 yearly visual and 12 yearly major PSSR inspections. The volume of each inspection type is based on the time since the last inspection for each individual PIG Trap.
- Any defects identified require resolution and remediation within defined timescales.
- The volumes of remediation work have been determined based on:
    - the number and type of defects currently identified
    - the number of defects forecast to arise during the investment period
    - the criticality of the PIG Trap to the predicted programme of Pipeline In-line Inspections.

17.10. Where defects are identified during the PSSR inspections then the appropriate intervention will be undertaken to restore the asset to operation, based on the current information the proposed interventions are:

17.11. Minor Defects Resolution, 28 in RIIO-2 and 50 in RIIO-3, including:

- Refurbishment – used to remedy external corrosion or cracking issues, minor redressing of the PIG Trap and reinstatement of the coating.
- Partial Replacement - used when a specific element of the PIG trap is the only failing part of the system and is impacting its overall performance.

17.12. Major Defects Resolution, 4 in RIIO-2 and 7 in RIIO-3, includes either:

- These interventions have been considered on whole life cost grounds when the ongoing cost of refurbishment and repair is greater than the cost of removal or replacement.
- Full Replacement – including the removal of the existing PIG trap and replacement with a new PIG trap. This can only be implemented when the PIG trap is 36' diameter and above or when the site conditions, such as access, mean that the portable PIG Trap cannot be used.

- Removal - removal of the existing PIG trap and replacement with connections for temporary PIG trap installation and suitable bypass pipe-work for ongoing valve operations. This is used only when the PIG trap is less than 36' diameter and when the site conditions, such as access, mean that the portable PIG Trap can be used.

17.13. The proposed mix of interventions and programme of work will be continually reassessed and reprioritised using the results of the ongoing PIG Trap inspections and any variations in the programme of Pipeline In-line Inspections.

Benefits of Investment

Defects

17.14. To maintain PSSR compliance and access for ILI runs on pipelines PIG Trap defects will all be remediated by the end of 2031. This compares with a forecast to rise to 32 by the end of 2026 and up to 57 by the end of 2031 without investment.

Preferred Option

17.15. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the PIG Trap assets in the investment period. [redacted]:

Intervention Volumes

[redacted]

Asset Health Spend Profile

17.16. The profile of investment in the PIG Trap assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

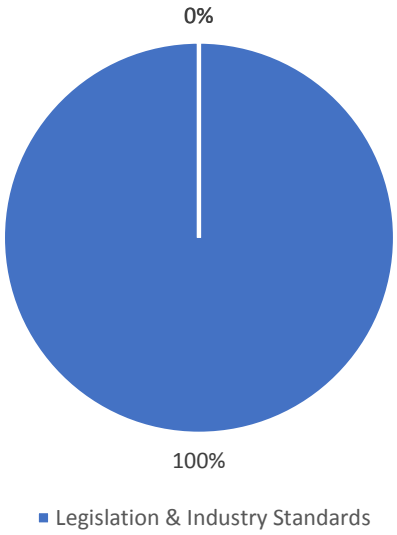
Investment Profile

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Pig Trap	420	840	350	770	1,889	1,189	1,959	2,169	1,959	420
Total	420	840	350	770	1,889	1,189	1,959	2,169	1,959	420
	4,268					**7,696**				

Intervention Drivers

17.17. The following chart shows the breakdown of investment across each of the intervention drivers. This shows that all of the investment consists of interventions that are driven by legislation and based on industry standards.

RIIO-2 PIG Traps Intervention Drivers[3]



Preferred Programme CBA

17.18. We are targeting an appropriate level of asset health investment to mitigate the reliability, safety and environmental risks from an ageing asset base.

17.19. In line with HM Treasury Green Book advice and Ofgem guidance we have appraised whether investment in pig traps is value for money. We have considered costs over a 45-year period in a full cost benefit analysis (CBA).

17.20. The CBA shows that investment in these assets is marginally non cost beneficial over the 45-year period. This is shown below:

Cost Benefit Analysis Summary[4]

	10 years	20 years	30 years	45 years
Present Value costs (£m)	£4.01	£9.23	£14.36	£20.87
Present Value H&S benefits (£m)	£0.00	£0.00	£0.01	£0.05
Present Value non H&S benefits (£m)	£0.21	£1.54	£5.46	£18.42
Net Present Value (£m)	£(3.80)	£(7.68)	£(8.88)	£(2.40)

17.21. Despite these findings, we consider this to be the right level of investment for these assets. The proposed investment is the lowest whole life cost to maintain the operation of the PIG Trap assets that are essential in maintaining our statutory ability to inspect our pipelines assets.

17.22. Overall our stakeholders and consumers want us to manage asset health. The investment proposed in RIIO-2/RIIO-3 maintains asset health through:

[3] See Appendix A for intervention driver category definitions

[4] A14.17.3 PIG Traps CBA

- Undertaking the mandated inspections and revalidation work on PIG Traps at the defined frequencies
- Resolving any issues that are found because of the inspections in the most economical way whilst maintaining the operational and performance requirements of the NTS.

17.23. This is the right level of investment to manage asset deterioration and ensure legal compliance. Failure to invest at this level will mean we are not delivering the high standards of health and safety that our stakeholders and consumers expect from us and will risk failing health and safety standards.

17.24. Failure to invest at this level impacts negatively on our ability to inspect and therefore target the cost beneficial investment identified for pipelines. We note that the summation of pipelines and PIG trap investment is highly cost beneficial.

17.25. We have used the potential range of unit cost variance to assess the sensitivity of the Cost Benefit Analysis to the upper and lower limits. Whilst the level of cost benefit and the payback period changes as the unit costs vary, the investment remains marginally non-cost beneficial across the range of unit costs over the 45 year period. The potential variation in unit costs does not cause our decision of the level of investment to be changed.

Net Benefits of Upper and Lower Unit Cost Sensitivity

17.26. We do not consider that delaying or deferring investment to make this more cost beneficial is acceptable. Across our stakeholders there is little support for increases in safety risk or risk of failing legal standards.

18. PIG Traps - Preferred Option Scope

18.1. The section summarises our preferred investment plan required to deliver acceptable and affordable outcomes for our stakeholders.

Preferred Option

18.2. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the PIG Trap assets in the investment period. [redacted]:

Intervention Volumes

[redacted]

Asset Health Spend Profile

18.3. The profile of investment in the PIG Trap assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

Investment Profile

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Pig Trap	420	840	350	770	1,889	1,189	1,959	2,169	1,959	420
Total	420	840	350	770	1,889	1,189	1,959	2,169	1,959	420
	4,268					**7,696**				

Delivery

18.4. At this point in time the delivery of our RIIO-2 and RIIO-3 plans are in principle deliverable based on initial assessments of work. We will regularly review the plan to consider any known or changing constraints, customer impacts and bundling opportunities. In the event of churn our plan must be re-optimised to reflect the impact of the change, and provide an opportunity to reconsider the efficient timing of delivery.

18.5. We recognise that many of our asset classes are co-located across the NTS pipe network and sites. Much of our investment delivery also requires outages of the associated pipelines or plant and equipment. The availability of outages is extremely limited across most of the NTS due to the radial nature of the network. It is therefore most efficient from both financial and network risk points of view to bundle investment across asset classes within the same outage period and this may involve taking an outage on a large section of pipework and working on multiple assets/workfaces simultaneously. To achieve this the assets need to be isolated, vented, repaired/replaced and then returned to service for the duration of their technical lives without further intervention a period which could be in the region of 25 years. The cost of recompression for a large section of the network is estimated to be in the region of

£0.25m. A systematic approach therefore maximises the work undertaken in any outage whilst ensuring efficient delivery through minimised project overheads.

18.6. This approach is particularly effective when applied at a feeder level or for a whole site. In which case the preparatory inspection, investigation, risk assessment, planning and procurement activities can be completed as far as possible before the outage. This allows the maximum amount of intervention and risk reduction to be bundled into a single 'campaign' across the length of the feeder. During RIIO-1 this has proved to be an extremely efficient and effective approach to delivery of our programmes of work.

18.7. We recognise that whilst this is in many cases the most efficient method of delivery there are still individual or groups of assets that present a risk to our performance that do not 'fit' into the planned 'campaign' approach. We will ensure that these risks are remediated as efficiently as possible through individual or small groups of targeted interventions.

18.8. A small number of locations on the network require an alternative solution to the usual outage approach to mitigate the risk of disruption to customer supply. This could be for example due to customers on single network spurs. While it may be possible in some cases to negotiate commercial solutions to this, costs per day are expected to be significant and it is likely that an alternative asset solution will be required in the form of stopples (bypasses). We will seek to identify alternative more efficient solutions with our delivery units and suppliers as the nature of the interventions on each site becomes clearer through our survey work.

18.9. Where asset interventions do not require outages then the campaign approach will still be applied to maximise the opportunity for delivery of the same type of work across many locations. This enables efficient procurement through significant volumes of common works.

Sleeves (£4.6m)

19. Sleeves - Equipment Summary

19.1. Pipeline protection sleeves consist of a casing installed around the Pipeline at the time of construction to mitigate the risk of a Pipeline failure at a specific location, to protect the pipeline from external interference or to facilitate construction. There are three classes of sleeve:

- Class 1 – to protect members of the public, or specific locations / installations, from the consequences of failure of a pipe. These also protect the pipe from external interference.
- Class 2 – to protect the pipeline solely from external interference and consist of concrete sleeves around the pipeline, concrete slabs above the pipeline?
- Class 3 – facilitate the construction of the pipeline

19.2. Class 1 sleeves consist of a steel sleeve surrounding the Pipeline with a gap between them that is filled with Nitrogen to 1bar. The purpose of the steel sleeve is to contain and divert the energy from any gas escape or ignition away from the point of failure to the ends of the sleeve where the consequences are less. E.g. for a pipeline laid under a major road the sleeve would be present for the entire width of the road crossing and extend to a safe distance from either side.

19.3. The purpose of the nitrogen is to provide in the gap between the pipeline and the sleeve is an inert atmosphere in the annulus between the outside of the pipeline and the inside of the surrounding sleeve, preventing corrosion from taking place to either the pipeline or the sleeve.

Location and Volume

19.4. There is a total of 1,955 sleeves that are installed on the Pipeline throughout the NTS. They are primarily installed across in areas of high consequence or where remediation of corrosion defects would be difficult and expensive. These locations include:

- Significant road crossings such as motorways and major roads
- Pipelines crossing under railways
- Proximity to housing or other populated areas.

Pressure Ratings

19.5. The sleeves are fitted around or in proximity to the NTS Pipelines which operate up to a maximum operating pressure of between 70 and 94 barg. Nitrogen sleeves contain gas at a pressure of up to 1 bar and are not subject to PSSR.

20. Sleeves - Problem Statement

20.1. The components that allow the sleeves to be tested and maintained and the seals between the ends of the sleeves and the pipeline suffer deterioration due to corrosion and wear. This allows the Nitrogen to escape and water ingress into the gap between the sleeve and the pipeline. The ingress of water causes corrosion to the Pipeline. The investigation and remediation of the corrosion under the Nitrogen sleeve is very expensive due to the presence of the sleeve and the location of the installation – under railways, major roads etc.

20.2. NG are experiencing an ongoing rate of failure of the components of the sleeve which is presenting a risk to the integrity of the pipeline.

20.3. The photo below shows a mock-up of a nitrogen sleeve as part of a test for an alternative pipe/sleeve annulus fill:

Nitrogen Sleeve Example

Drivers for Investment

20.4. The investment in sleeves is driven by the deterioration of the asset.

20.5. **Asset Deterioration** - the nitrogen sleeves and their components deteriorate due to age and wear. The pressure of the Nitrogen cannot be maintained and water ingresses into the gap between the sleeve and the pipeline.

Impact of No Investment

20.6. In appraising asset health investment, we have considered how the asset deterioration can impact on several outcomes:

- Reliability risk
- Environmental risk
- Safety risk
- Societal risk.

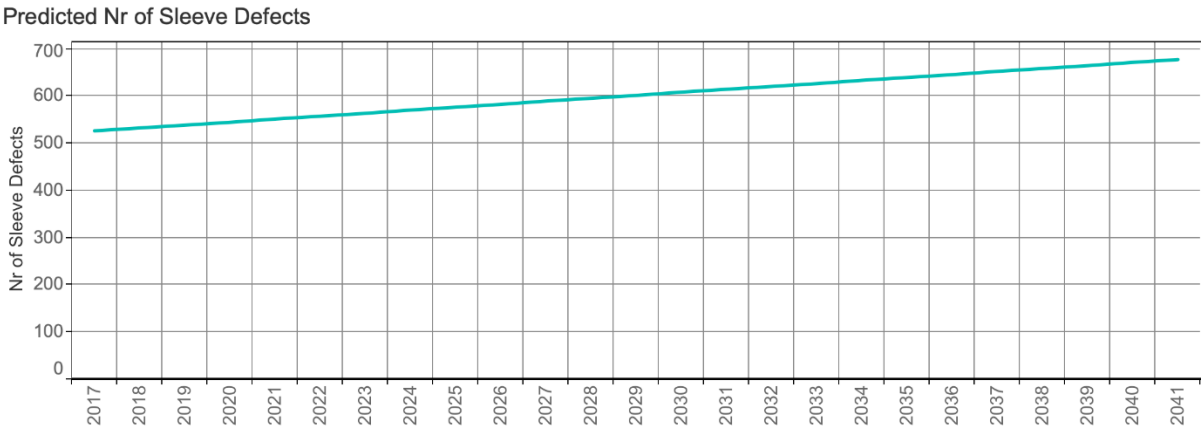
20.7. A critical part of our appraisal method is to assess is the Do-Nothing position. This is the situation where we do not invest proactively in our asset base (i.e. we fix on fail), ensuring any reactive investment meets all health and safety requirements. The baseline position under each area of spend is reactive opex only, with no capex included in the baseline. This is a baseline against which the incremental investment is compared to the incremental benefits. This is critical for developing value for money business plans.

20.8. Lack of investment in the Nitrogen sleeves directly results in the inability of the sleeve to contain Nitrogen at the specified pressure of 1 bar. This has a direct result of leakage of the nitrogen to atmosphere and the ability for water to ingress. The water causes the corrosion of the pipeline, reducing its structural integrity and ultimately reducing its fitness for purpose.

20.9. In developing our baseline, we have used the same probability of failure and probability of consequence estimates, and forward-looking predictive assessment as used in developing proposed options for investment.

20.10. The chart below shows the number of defects starting from current levels captured in Ellipse work order data and predicted for future years using the equipment failure deterioration models in our NOMs methodology developed in 2017.

Predicted number of Sleeve Defects



20.11. Out of a total of 1,193 sleeves there are currently 527 with known defects and a further 328 that have required nitrogen top-ups at the last inspection.

20.12. The currently identified 527 sleeve defects will remain unresolved and are forecast to rise to 607 by the end of 2031.

20.13. Unless resolved these defects will increase the rate of corrosion on the associated pipeline in areas of high consequence that are also difficult to gain access to and therefore expensive to remediate.

20.14. The Do-Nothing position shows an increase in risk over the RIIO-2 and RIIO-3 periods. This is not in line with the outcomes our consumers and stakeholders want to see.

20.15. This do-nothing baseline does not align with the outcomes our consumers and stakeholders have consistently told us they want to us to achieve. The do-nothing baseline involves an increase in safety risk, which is an unacceptable outcome for our consumers and stakeholders.

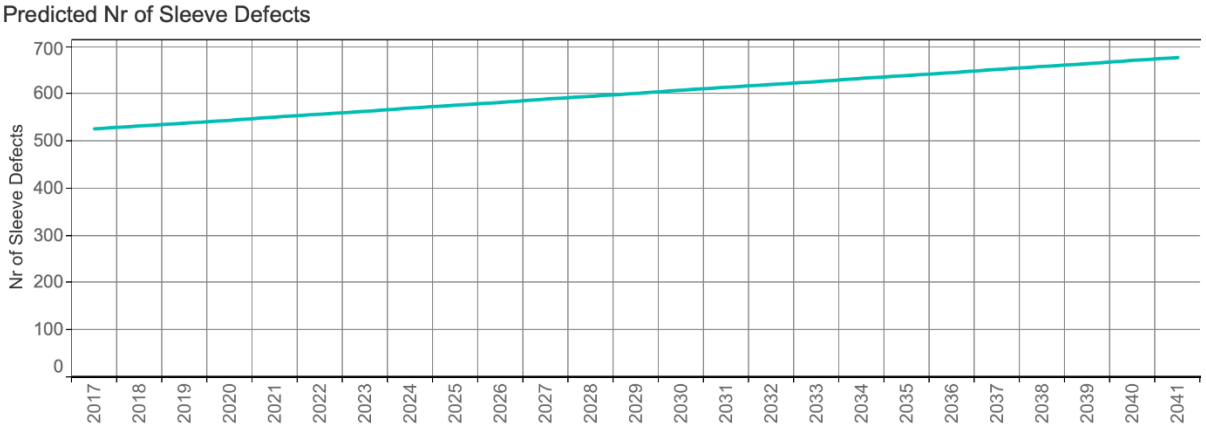
Spend Boundaries

20.16. The proposed investment applies to all Nitrogen Sleeves that are present on the NTS. There is no investment proposed in any of the other sleeve types within this investment case.

21. Sleeves - Probability of Failure

21.1. The chart below shows the predicted number of sleeve defects with of no investment

Predicted number of Sleeve Defects



Probability of Failure Interventions

21.2. Several Pipelines assets are defined as only delivering Consequential Interventions based upon the following definitions:

"Any intervention on a network asset, or other infrastructure asset, that modifies the probability of failure, or consequence of failure of another network asset. A consequential asset can include, for example:

- installation or removal of physical infrastructure designed to prevent damage to adjacent assets in the event of an asset failure (e.g. installation of a blast wall),
- addition or disposal that increases or decreases the resilience of a local or regional network and hence modifies the consequence of failure of other asset(s) in the locality or region."

Consequential Interventions

21.3. These assets, that reduce or increase the PoF of the associated pipeline asset, are listed in the table below:

Sleeves Investment Drivers

NARMs Asset Intervention Category	Secondary Asset Class
Consequential Interventions (Non-risk tradeable)	Impact Protection - Nitrogen Sleeves

21.4. Our NOMs Methodology attempts to model the indirect benefits delivered by these assets in terms of the reduction in PoF or Consequence of Failure (CoF) upon a related and/or adjacent asset (e.g. the benefit of air intakes on the numbers of compressor trip and vents). These quantified, but indirect, impacts are used within the CBAs accompanying this justification report but are not considered to be reliable enough for use as a NARMs monetised risk metric.

Sleeves Interventions

21.5. The intervention options for Sleeves are shown in the table below:

Sleeves Interventions

Intervention	SAC	Intervention Category
A22.16.2.1 / Nitrogen Sleeve Remediation - Minor	Impact Protection	Minor Refurbishment
A22.16.2.2 / Nitrogen Sleeve - Grouting	Impact Protection	Replacement
A22.16.2.3 / Nitrogen Sleeve Remediation - Major	Impact Protection	Major Refurbishment

Data Assurance

21.6. All PoF and CoF values are taken from the National Grid Gas Transmission 'Methodology for Network Output Measures' (the Methodology). The Methodology was originally submitted for public consultation in April 2018, with three generally favourable responses received in May 2018. On this basis, Ofgem were happy to provisionally not reject the Methodology pending further work to:

- Produce a detailed Validation Report, confirming the validity of data sources used in the Methodology
- Test a range of supply and demand scenarios and incorporate an appropriate scenario to best represent Availability and Reliability risk

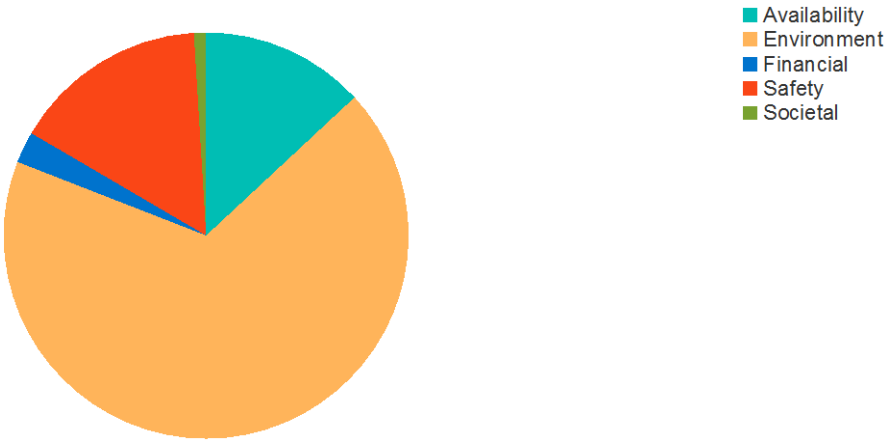
21.7. A review of the Methodology by independent gas transmission experts has been carried out and several improvements identified and incorporated.

21.8. At the time of writing, the final Validation Report has been submitted to Ofgem. We understand that once this work is complete Ofgem will formally "not reject" the Methodology and a License change progressed to restate our RIIO-1 targets in terms of monetised risk commenced.

22. Sleeves - Consequence of Failure

22.1. The pie chart below shows the stakeholder impacts expected from failures occurring on Sleeves. The charts show the relative numbers of consequence events, not relative monetised risk.

Stakeholder Impact – Sleeve Failure



22.2. The contribution of individual service risk measures towards the overall risk for Impact Sleeves (including protective sleeves and slabs) can be explained as follows, in order of significance. Impact Sleeve benefits are assessed in terms of the level of protection they provide to the primary pipeline asset:

- Environmental risk is associated with the loss of gas arising from a leak or rupture of the pipeline caused by external interference or corrosion.
- Safety risk is associated with the potential for third-party damage, or external interference, causing a pipeline leak or rupture. Nitrogen sleeves also provide additional protection against pipe wall corrosion. The risk of an external interference event is much more likely without the protection again impact afforded by slabs and sleeves. Where the pipeline passes near populated areas the Safety risk arising from ignition of the leak or rupture is relatively large. Corrosion risk is also higher where a nitrogen sleeve is in poor condition.
- Availability risk is associated with the potential outages associated with the shut-down of a pipeline for repair of a leak or rupture caused by external interference or corrosion.
- Financial risk is mostly associated with the OPEX costs of operating and maintaining the network at the current level of risk
- Societal risk is largely associated with disruption to road or rail transportation following asset failure. The likelihood of a fire or explosion is small, and many assets are not near to transportation links. Therefore, the overall societal risk associated with pipeline asset failure is small.

23. Sleeves - Options Considered

23.1. In this section, we outline the options we have considered.

Potential Intervention Options

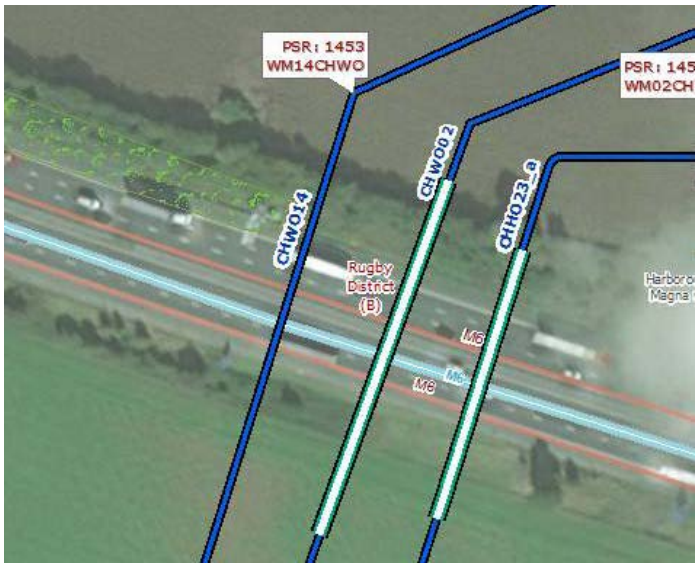
23.2. The following individual inspections and intervention categories apply to the Sleeves assets:

- **Inspection** - Annual maintenance is performed to check that the nitrogen pressure remains between 0.6 bar and 1.0 bar. Pressure loss between inspections is an indication that nitrogen is leaking from the sleeve to atmosphere and the inert atmosphere will not be preserved.
- **Refurbishment** - Remediation of the leaking sleeves requires excavation of the sleeve at the fill point location to replace the failed components including hoses, valves, and nitrogen fill points. This applies to all types of seal where the cause of the leak is attributed to the riser pipe, valve, flange, hose connection or hose to the fill and test point.
- **Refurbishment** – Flexible End Seal Sleeves Only. Refurbishment of the end seals for those sleeves that have flexible end seals. This requires significant excavation and an outage of the pipeline. This intervention is only carried out when the leak has been directly attributed to the flexible end seal. All other components are also replaced at the same time.
- **Removal** - There is the option to remove the nitrogen within the sleeve and replace this with an inert grout that has corrosion inhibitors within it. This is the preferred intervention option.

Feeders crossing the M6

23.3. The image below shows two of the three feeders crossing the M6 in the midlands, installed with nitrogen sleeves. The third was constructed to a later standard as is a heavy wall pipeline.

Sleeves across the M6



Intervention Unit Costs

23.4. The total RIIO-2 investment for the Impact Sleeves represents 3% of the Pipelines investment theme. The unit costs that support the Impact Sleeves investment have been developed using a large proportion of historical outturn cost data points, which need to be verified. Where this has not been possible other estimation methods have been applied. Full details of our RIIO-2 unit cost methodology can be found in the Asset Health Unit Cost Annex.

23.5. Sleeve grouting is considered a specialist activity and will be used, where appropriate, to avoid more costly alternative cut out and replacement interventions. Currently there is only one supplier as an approved vendor considered competent to undertake and estimate these works.

23.6. The table below provides the unit costs for all interventions for Impact Sleeves.

Unit costs for Interventions – Nitrogen Sleeves

Intervention	Cost (£)	Unit	Evidence	Data Points	Overall value in BP
Nitrogen Sleeve					
A22.16.2.3 / Nitrogen Sleeve Remediation - Major	[redacted]	Per Asset	Outturn	1	£ 2,380,736
A22.16.2.2 / Nitrogen Sleeve - Grouting	[redacted]	Per Asset	Estimated - Quotation	1	£ 1,474,725
A22.16.2.1 / Nitrogen Sleeve Remediation - Minor	[redacted]	Per Asset	Outturn	1	£ 786,899

24. Sleeves - Programme Options

24.1. Our aim in developing the investment plan is to deliver value to our consumers and stakeholders.

24.2. As described in the section below ‘Sleeves - Business Case Outline and Discussion – Investment Decision Approach’ our investment in Nitrogen Sleeves is driven from the results of inspections and maintenance. If following an inspection issues are identified then analysis is undertaken and the lowest whole life cost intervention that meets the technical requirements and legal obligations is implemented.

24.3. The proposed programme is based on the best available information and represents the lowest whole life programme of investment over RIIO-2 and RIIO-3. The proposed investment is the “do minimum” option to maintain compliance.

24.4. Whilst further options could be considered, due to the nature of these assets and the simplicity of the interventions to be done, it is not prudent or affordable to consider options which would add unnecessary cost to the plan. We have therefore not considered any further programme options as any of those would be an increase in initial investment and overall whole life cost from this proposed position.

25. Sleeves - Business Case Outline and Discussion

25.1. In this section, we set out our overall investment plan for Sleeves. This section demonstrates why the proposed investment levels are the right levels to ensure the health and reliability of these assets for the investment period and beyond.

Key Business Case Drivers Description

25.2. These assets deteriorate over time and with use, which in turn leads to their inability to perform their required function.

25.3. Therefore, in developing our risk forecasts and proposed plans we have considered the impact of the following drivers for investment in the Nitrogen Sleeves is:

- Asset Deterioration.

Business Case Summary

25.4. In appraising asset health investment, we have considered how assets can impact on several outcomes:

- Reliability risk
- Environmental risk
- Safety risk
- Societal risk

25.5. Failures of Sleeves impacts primarily on safety.

Outcomes Delivered

25.6. Maintaining the health of these assets is important in ensuring we continue to deliver the required network capability safely. The specific outcome associated with this investment is to:

- Reduce the risk that Nitrogen Sleeves present to the structural integrity of the pipeline

25.7. Our proposed investment will ensure that we maintain our low levels of safety risk across this asset.

Stakeholder Support

25.8. Consumer and stakeholder research and engagement has been integral to the development of our asset health investment plans. Early discussions realised that to engage in meaningful dialogue, our plan outputs should be presented at a programme rather than asset level of detail. This is due to the integrated nature of our Asset Health plan which makes it challenging to disaggregate and engage on individual elements. For details of our stakeholder engagement approach please refer to 'I want to take gas on and off the system where and when I want' Chapter of the GT submission

Investment Decision Approach

25.9. To deliver the outcomes for the investment period the sleeves a balance of the intervention categories. The decision on the volume of each of the interventions required on the Nitrogen Sleeves during the investment period is driven by:

- Annual maintenance to inspect the visible elements of the asset and to check the pressure of the Nitrogen and top up if required.
- Nitrogen sleeves were installed at locations to protect the pipeline from population and vice versa at locations of high population density, such as major traffic (road/rail) crossings. Remediation of a corrosion feature within a nitrogen sleeve at these locations are unfeasible and therefore the remediation would almost always require a pipeline replacement or diversion. On that basis, the driver is to remediate all leaking nitrogen sleeves to prevent the situation occurring or worsening.
- The prioritisation of the remedial work in RIIO-1 and proposed into RIIO-2/RIIO-3 would be to address the sleeves losing nitrogen that also have coincident corrosion features on the pipeline within the sleeve that has been identified through the last ILI. This identifies where the inert atmosphere is not being preserved and corrosion is taking place. On the basis that the last ILI result may up to 15 years old, and the only way to understand whether corrosion is present would be to perform a new ILI, it is far more economical to repair the sleeve.
- The next priority would be sleeves losing nitrogen at the highest population crossings (motorways etc.).
- The volumes of remediation work for the period have been determined based on:
    - time based inspections
    - the number and type of defects currently identified
    - the number of defects forecast to arise during the investment period

25.10. The investment proposed during the period is to remediate, at lowest whole, life costs, the defects that have been currently identified and resolve those that are identified through maintenance during the period. An individual whole life cost assessment will be made for each defect and the appropriate intervention undertaken. Based on the currently available information the volumes of each intervention required are shown in the table in the 'Preferred Option' section below.

25.11. The proposed mix of interventions and programme of work will be continually reassessed and reprioritised using the results of the ongoing maintenance and inspections.

25.12. The currently identified 527 defects together with any additional defects identified during the period will be remediated by the end of 2031.

Preferred Option

25.13. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the nitrogen sleeves in the investment period. [redacted]:

Volumes for each Intervention

[redacted]

Asset Health Spend Profile

25.14. The profile of investment in the nitrogen sleeves, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

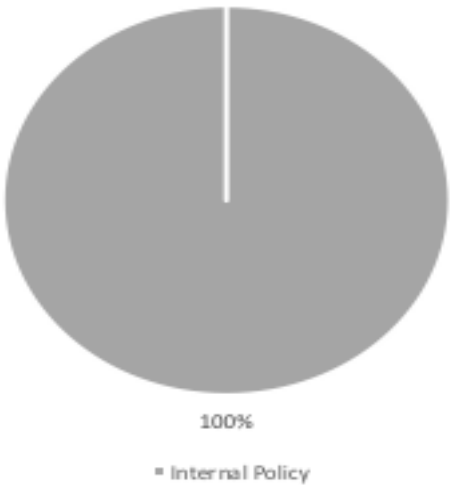
Investment Profile – Nitrogen Sleeves

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Impact Protection	0	0	1,548	1,548	1,545	7,580	7,674	7,704	7,678	7,654
Total	0	0	1,548	1,548	1,545	7,580	7,674	7,704	7,678	7,654
	4,642					**38,291**				

Intervention Drivers

25.15. The following chart shows the breakdown of investment across each of the intervention drivers. This shows that all of the investment consists of interventions that are driven by internal policy.

RIIO-2 Sleeves Intervention Drivers[5]



[5] See Appendix A for intervention driver category definitions

Preferred Programme CBA

25.16. We are targeting an appropriate level of asset health investment in sleeves to mitigate safety risks from an ageing asset base.

25.17. In line with HM Treasury Green Book advice and Ofgem guidance we have appraised whether investment in Nitrogen Sleeves is value for money. We have considered costs over a 45-year period in a full cost benefit analysis (CBA).

25.18. The CBA for the Nitrogen Sleeves investment over the period is cost beneficial over the 45-year period. This investment pays back within 10 years, and over 45 years is significantly cost beneficial. This is shown below.

Cost Benefit Analysis Summary – Nitrogen Sleeves[6]

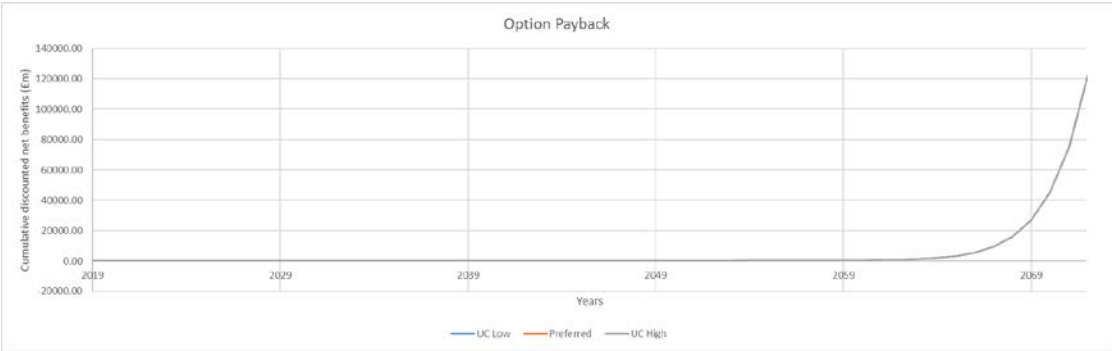
	10 years	20 years	30 years	45 years
Present Value costs (£m)	£12.38	£21.29	£29.16	£36.45
Present Value H&S benefits (£m)	£3.01	£9.92	£21.28	£776.53
Present Value non H&S benefits (£m)	£35.17	£132.62	£316.34	£4,839.73
Net Present Value (£m)	£25.80	£121.24	£308.47	£5,579.82

25.19. We have challenged whether this is the right programme of work. Through our asset management processes, we have assessed whether our plans are the best mix of interventions for our stakeholders and consumers.

25.20. The investment is the least whole-life cost programme required to maintain compliance, ensure we manage asset deterioration and maintain levels of safety risk. It will ensure we deliver the outcomes that consumers and stakeholder tell us they want us to meet.

25.21. We have used the potential range of unit cost variance to assess the sensitivity of the Cost Benefit Analysis to the upper and lower limits. Whilst the level of cost benefit and the payback period changes as the unit costs vary, the investment remains cost beneficial across the range of unit costs. The potential variation in unit costs does not cause our decision of the level of investment to be changed.

Net Benefits of Upper and Lower Unit Cost Sensitivity



25.22. Across our stakeholders there is little support for keeping the costs the same as in RIIO-1, given the unacceptable consequential increase in risk.

[6] A14.17.2 Impact Sleeves CBA

26. Sleeves - Preferred Option Scope

26.1. The section summarises our preferred investment plan required to deliver acceptable and affordable outcomes for our stakeholders.

Preferred Option

26.2. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the nitrogen sleeves in the investment period. [redacted]:

Volumes for each Intervention

[redacted]

Asset Health Spend Profile

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Delivery

26.4. At this point in time the delivery of our RIIO-2 and RIIO-3 plans are in principle deliverable based on initial assessments of work. We will regularly review the plan to consider any known or changing constraints, customer impacts and bundling opportunities. In the event of churn, our plan must be reoptimised to reflect the impact of the change and provide an opportunity to reconsider the efficient timing of delivery.

26.5. We recognise that many of our asset classes are co-located across the NTS pipe network and sites. Much of our investment delivery also requires outages of the associated pipelines or plant and equipment. The availability of outages is extremely limited across most of the NTS due to the radial nature of the network. It is therefore most efficient from both financial and network risk points of view to bundle investment across asset classes within the same outage period and this may involve taking an outage on a large section of pipework and working on multiple assets/workfaces simultaneously. To achieve this, the assets need to be isolated, vented, repaired/replaced and then returned to service for the duration of their technical lives without further intervention a period which could be in the region of 25 years. The cost of recompression for a large section of the network is estimated to be in the region of

£0.25m. A systematic approach therefore maximises the work undertaken in any outage whilst ensuring efficient delivery through minimised project overheads.

26.6. This approach is particularly effective when applied at a feeder level or for a whole site. In which case the preparatory inspection, investigation, risk assessment, planning and procurement activities can be completed as far as possible before the outage. This allows the maximum amount of intervention and risk reduction to be bundled into a single 'campaign' across the length of the feeder. During RIIO-1 this has proved to be an extremely efficient and effective approach to delivery of our programmes of work.

26.7. We recognise that whilst this is in many cases the most efficient method of delivery there are still individual or groups of assets that present a risk to our performance that do not 'fit' into the planned 'campaign' approach. We will ensure that these risks are remediated as efficiently as possible through individual or small groups of targeted interventions.

26.8. A small number of locations on the network require an alternative solution to the usual outage approach to mitigate the risk of disruption to customer supply. This could be for example due to customers on single network spurs. While it may be possible in some cases to negotiate commercial solutions to this, costs per day are expected to be significant and it is likely that an alternative asset solution will be required in the form of stopples (bypasses). We will seek to identify alternative more efficient solutions with our delivery units and suppliers as the nature of the interventions on each site becomes clearer through our survey work.

26.9. Where asset interventions do not require outages then the campaign approach will still be applied to maximise the opportunity for delivery of the same type of work across many locations. This enables efficient procurement through significant volumes of common works.

Water Course Crossings (£2.1m)

27. Water Course Crossings - Summary

27.1. A Water Course Crossing is defined as a location where a pipeline has been constructed in the bed of a watercourse which may include streams, rivers, navigable waterways, estuaries, large expanses of water, shore approaches and other shallow waters affected by adverse water and associated ground conditions.

27.2. The depth of ground cover above the pipeline is essential to managing the risk of damage to the pipeline by third parties and erosion under pipeline from water flow.

Location and Volume

27.3. There are water course crossings located throughout the NTS. Nine of these are crossings tidal and navigable rivers and are classified as major crossings.

Water Course Crossings

Pipeline	River	Length of Crossing (km)
Feeder 13 – Arbroath to Haddington – (diam 1,050 mm)	Firth of Forth	17.3
Feeder 12 – Kirriemuir to Bathgate - (diam 900 mm)		3.8
Feeder 13 – Arbroath to Haddington – (diam 1,050 mm)	Firth of Tay	6.2
Feeder 12 - Kirriemuir to Bathgate - (diam 900 mm)		0.3
Feeder 1 – Paull to Skitter – (diam 600 mm)	Humber	3.1
Feeder 1 – Paull to Skitter - (diam 600 mm)		3.1
Feeder 5 – Tilbury to Gravesend (East) - (diam 600 mm)	Thames	1.2
Feeder 5 – Tilbury to Gravesend (West) - (diam 600 mm)		1.2
Feeder 14 – Barrington to Kenn South - (diam 500 mm)	Exe	1.4
Feeder 14 – Pennington - (diam 300 mm)	Duddon	2.4

27.4. There is currently a total of 598 minor water course crossings on the NTS.

27.5. The classification of the crossing is used to determine the risk level from damage and erosion should the level of cover not be maintained. This risk classification is used to determine the inspection frequency of the pipeline where is crosses the water course. NG is currently undertaking a reclassification of the Water Crossings to better reflect this threat.

Pressure Ratings

27.6. The depth of ground cover at water crossings protects the NTS Pipeline which operates up to a maximum operating pressure between from 70 and 94 bar.

28. Water Course Crossings - Problem Statement

28.1. There are 47 locations where the level of cover above or support below the pipeline in a river crossing has been eroded and presents an increased risk of third-party damage to the Pipeline. These in turn present a risk to its structural integrity and any associated potential safety and environmental implications. This is a continual issue that will need to be monitored, assessed and remediated on an ongoing basis.

28.2. Of those 47 locations, 9 have been risk assessed and need remediation works in RIIO-2 and RIIO-3 along with up to a further 18 that are predicted to arise during the period.

28.3. Lack of investment in the inspection of watercourse crossings will lead to an unknown level of risk of third-party damage to Pipelines in these areas.

Drivers for Investment

28.4. The key drivers for investment in the watercourse crossings are:

- Erosion of cover above the Pipeline increasing the risk of third-party damage
- Erosion of ground below the Pipeline potentially leading to lack of structural support and 'spanning'
- PSR Legislation.

28.5. The investment in watercourse crossings is driven by legislation together with the environment surrounding and impacting the Pipeline.

28.6. **Erosion of Cover -** Over time the level of cover over the pipeline may erode. Without sufficient cover, the pipelines may be susceptible to additional loading from the flow of water, potential damage from third party interference or impact damage from marine traffic. For the major crossings, the risk is from anchor drag on the large shipping vessels. For minor crossings, the risk is exposure or a potential strike from an excavator (or dredge) clearing the riverbed and banks.

28.7. **Pipeline Spanning -** Where pipelines are laid across rivers or estuaries within or on the bed material there is a risk that tidal scouring can lead to the pipeline becoming exposed. Once the crown of the pipe is exposed interaction between the tidal flow and the pipe can cause vortices which remove bed material resulting in spanning. Over time, this spanning can result in the mechanical deformation of the pipeline under its own weight and tidal action can lead to rupture. Spanning can also result from flash flooding or river wandering typically leading to exposure of the pipe at the riverbank where it drops to pass under the river.

28.8. **Legislation -** The key driver for investment in Pipeline Water Course Crossings is to ensure compliance with PSR to protect members of the public.

Impact of No Investment

28.9. In appraising asset health investment, we have considered how assets can impact on several outcomes:

- Reliability risk
- Environmental risk
- Safety risk
- Societal risk.

28.10. A critical part of our appraisal method is to assess is the baseline position. This is the position where we do not invest proactively in our asset base (i.e. we fix on fail), ensuring any reactive investment meets all health and safety requirements. The baseline position under each area of spend is reactive opex only, with no capex included in the baseline. This is a baseline against which the incremental investment is compared to the incremental benefits. This is critical for developing value for money business plans.

28.11. Lack of investment in the inspection of watercourse crossings will lead to an unknown level of risk of third-party damage to Pipelines in these areas.

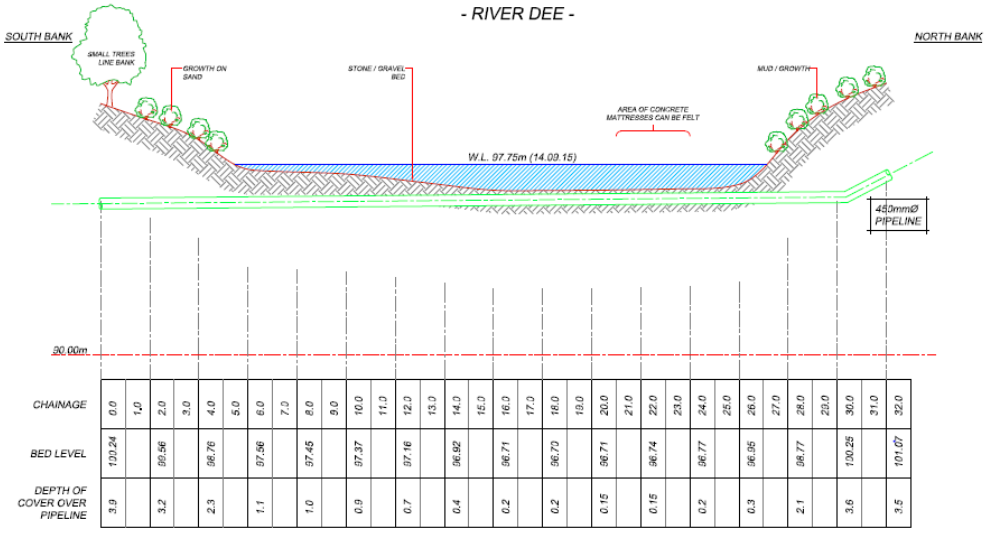
28.12. Any current or future issues of reduced cover will continue to deteriorate and present an increasing risk of damage to the Pipeline by either third parties or lack of structural support. Either of these could lead to the loss of containment of high-pressure gas and the associated impact on public safety, the environment and the effective operation of the NTS.

28.13. The Do-Nothing position does not align with the outcomes our consumers and stakeholder want and prefer. The Do-Nothing baseline presents an unacceptable safety risk to the public, along with increased levels of environmental risk.

Example of the Problem

28.14. The photo and drawing below show the river Dee with 15cm of cover over the pipeline.

Watercourse Crossing of the River Dee



CHAINAGE	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0	28.0	29.0	30.0	31.0	32.0
BED LEVEL	100.24		99.56		98.76		97.56		97.45		97.37		97.16		96.92		96.71		96.70		96.71		96.74		96.77		96.95		98.77		100.25		101.07
DEPTH OF COVER OVER PIPELINE	3.9		3.2		2.3		1.1		1.0		0.9		0.7		0.4		0.2		0.2		0.15		0.15		0.2		0.3		2.1		3.6		3.5

Spend Boundaries

28.15. The proposed investment applies to the NTS Pipeline where it crosses watercourses. The investment includes for reinstatement of depth of cover and spanning issues, any significant water course crossing issues that fall outside of the historical norms are not included.

29. Water Course Crossings - Probability of Failure

29.1. Several Pipelines assets are defined as only delivering consequential interventions based upon the following definitions:

> *"Any intervention on a network asset, or other infrastructure asset, that modifies the probability of failure, or consequence of failure of **another network asset**. A consequential asset can include, for example:*
>
> - *installation or removal of physical infrastructure designed to prevent damage to adjacent assets in the event of an asset failure (e.g. installation of a blast wall),*
> - *addition or disposal that increases or decreases the resilience of a local or regional network and hence modifies the consequence of failure of other asset(s) in the locality or region."*

Consequential Interventions

29.2. These assets, that reduce or increase the PoF of the associated pipeline asset, are listed in the table below:

Water Crossings Intervention Drivers

NARMs Asset Intervention Category	Secondary Asset Class
Consequential Interventions (Non-risk tradeable)	River Crossings

29.3. Our NOMs Methodology attempts to model the indirect benefits delivered by these assets in terms of the reduction in PoF or Consequence of Failure (CoF) upon a related and/or adjacent asset (e.g. the benefit of air intakes on the numbers of compressor trip and vents). These quantified, but indirect, impacts are used within the CBAs accompanying this justification report but are not considered to be reliable enough for use as a NARMs monetised risk metric.

Watercourse Crossing Interventions

29.4. The interventions for Watercourse Crossings are shown in the table below:

Water Crossings Interventions

Intervention	SAC	Intervention Category
A22.16.5.1 / Watercourse crossings (defect resolution)	River Crossings	Major Refurbishment
A22.16.5.2 / Watercourse crossings (Duddon Estuary)	River Crossings	Major Refurbishment

Data Assurance

29.5. All PoF and CoF values are taken from the National Grid Gas Transmission 'Methodology for Network Output Measures' (the Methodology). The Methodology was originally submitted for public consultation in April 2018, with three generally favourable responses received in May 2018. On this basis, Ofgem were happy to provisionally not reject the Methodology pending further work to:

- Produce a detailed Validation Report, confirming the validity of data sources used in the Methodology
- Test a range of supply and demand scenarios and incorporate an appropriate scenario to best represent Availability and Reliability risk

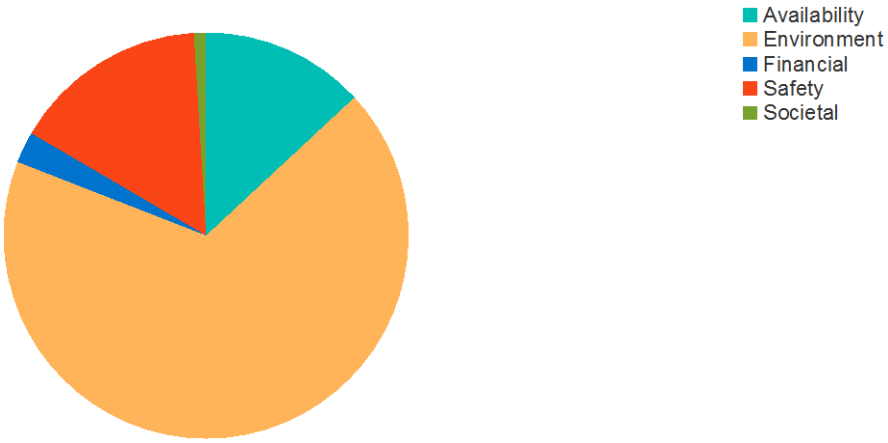
29.6. A review of the Methodology by independent gas transmission experts has been carried out and several improvements identified and incorporated.

29.7. At the time of writing, the final Validation Report has been submitted to Ofgem. We understand that once this work is complete Ofgem will formally “not reject” the Methodology and a License change progressed to restate our RIIO-1 targets in terms of monetised risk commenced.

30. Water Course Crossings - Consequence of Failure

30.1. The pie chart below shows the stakeholder impacts expected from failures occurring on water course crossings. The charts show the relative numbers of consequence events, not relative risk.

Stakeholder Impacts – Water course Crossing Failures



30.2. The contribution of individual service risk measures towards the overall monetised risk for Watercourse Crossings can be explained as follows, in order of significance. Watercourse crossings are assets which generate additional risk for the primary pipeline and poor condition Watercourse Crossing assets will further increase the pipeline risk:

- Environmental risk is associated with the loss of gas arising from a leak or rupture of the pipeline caused by external interference, corrosion or mechanical failure
- Safety risk is associated with the potential for third-party damage, or external interference, causing a pipeline leak or rupture. The risk of an external interference event is much more likely with a poor condition, or non-functional, crossing. Where the pipeline passes near centres of population the Safety risk arising from ignition of the leak or rupture is relatively large. Corrosion risk is also higher due to pipeline exposure
- Availability risk is associated with the potential outages associated with the shut-down of a pipeline for repair of a leak or rupture caused by external interference, corrosion or mechanical failure
- Financial risk is mostly associated with the costs of operating and maintaining the network at the current level of risk
- Societal risk is largely associated with disruption to road or rail transportation following asset failure. The likelihood of a fire or explosion is small and many assets are not near to transportation links. Therefore, the overall societal risk associated with pipeline asset failure is small.

31. Water Course Crossings - Options Considered

31.1. In this section, we outline the options we have considered in developing our asset health plans for pipelines in water courses.

Potential Intervention Options

31.2. In addition to the interventions that apply to all Pipelines, the following intervention categories have been considered for where they cross watercourses:

- **Inspection** - Surveys are undertaken every 1 to 15 years to ensure that the pipelines maintain an adequate depth of cover and that the condition of the banks of the watercourse do not present an integrity threat to the assets.
- **Reinstatement of Cover** - Replace cover the on pipeline with rock or concrete armour. This reduces the risk of mechanical damage to the Pipeline and significantly reduces the erosion that can lead to spanning.
- **Replace** - Replace the affected section of the Pipeline with a new section of heavy walled pipe. This heavy walled pipe reduces the risk of structural deformation and mitigates the impact of any damage to the pipe.
- **Diversion** - Lay a new section of Pipeline along an alternative route to avoid the issues at the current location.

Intervention Unit Costs

31.3. The total RIIO-2 investment for the Watercourse Crossings is £2m which represents 1% of the Pipelines investment theme. The unit costs that support the Watercourse Crossings investment have been developed using other estimation methods due to the spectrum of variances in the works that can be performed making obtaining supplier quotations difficult and unpractical.

31.4. The table below provides the unit costs for all the potential intervention categories to manage pipelines crossing water courses.

Unit Costs for Interventions – Watercourse Crossings

Intervention	Cost (£)	Unit	Evidence	Data Points	Overall value in BP
Watercourse Crossing					
A22.16.5.1 / Watercourse crossings (defect resolution)	[redacted]	Per asset	Estimated - Other	1	£ 1,855,000
A22.16.5.2 / Watercourse crossings (Duddon Estuary)	[redacted]	Per asset	Estimated - Quotation	1	£ 245,046

32. Water Course Crossings - Programme Options

32.1. Based on our experience the only credible programme option that maintains compliance with TD/1 standards and manages the risk on the NTS is to monitor water course crossings and reactively invest in issues that are identified.

32.2. For RIIO-2 and RIIO-3 the only intervention option that has been considered and included to resolve any identified issues is to reinstate the level of cover over the pipeline. This represents the “do minimum” option to maintain compliance and is the lowest whole life intervention to resolve the issue, manage the risk on the NTS and comply with standards and legal requirements. There are no diversions or replacements within the proposed programme of investment. Whilst further options could be considered, due to the nature of these assets and the simplicity of the interventions to be done, it is not prudent or affordable to consider options which would add unnecessary cost to the plan. We have therefore not considered any further programme options as any of those would be an increase in initial investment and overall whole life cost from this proposed position.

33. Water Course Crossings - Business Case Outline and Discussion

33.1. In this section, we set out our overall investment plan for Water Course Crossings. This section demonstrates why the proposed investment levels are the right levels to ensure the health and reliability of these assets for the investment period and beyond.

Key Business Case Drivers Description

33.2. The investment in watercourse crossings is driven by legislation together with the environment surrounding and impacting the Pipeline.

33.3. Therefore, in developing our risk forecasts and proposed plans we have considered the impact of the following drivers for investment in the watercourse crossings are:

- Erosion of cover above the Pipeline increasing the risk of third-party damage
- Erosion of ground below the Pipeline potentially leading to lack of structural support and ‘spanning’
- PSR Legislation.

33.4. Considering these drivers ensures that we develop plans that meet our legal obligations to intervene, and ensures we prioritise the right assets for investment.

Business Case Summary

33.5. In appraising asset health investment, we have considered how watercourse crossings can impact on several outcomes:

- Reliability risk
- Environmental risk

- Safety risk
- Societal risk.

33.6. Watercourse crossing impact on these outcomes, most notably safety and environmental risk.

Outcomes Delivered

33.7. More specifically, the desired outcome for this investment is to:

- Understand the nature of any issues where the pipeline crosses waterways and manage the risk of these to maintain the integrity of the pipeline
- Ensure continued compliance with PSR Legislation to protect members of the public.

Stakeholder Support

33.8. Consumer and stakeholder research and engagement has been integral to the development of our asset health investment plans. Early discussions realised that to engage in meaningful dialogue, our plan outputs should be presented at a programme rather than asset level of detail. This is due to the integrated nature of our Asset Health plan which makes it challenging to disaggregate and engage on individual elements. For details of our stakeholder engagement approach please refer to 'I want to take gas on and off the system where and when I want' [Chapter 9 of the GT submission].

Investment Decision Approach

33.9. To deliver the outcomes for the investment period the watercourse crossings require the right mixture of intervention categories. This includes:

- Surveys of all watercourse crossings are undertaken based on their classification and level of risk ranging from 1 to 15 years. The purpose of the watercourse crossing survey is to confirm that the pipeline remains buried, that the banks of the watercourse are in good condition and that there is adequate cathodic protection.
- The recommended minimum level of cover is 1.2m, which is stated in IGEM/TD/1. Where inspections show that the depth of cover is below this or other issues exist then a risk-based review is undertaken. This review includes:
- The nature of the water course, seasonal variations and severe weather variations, past flooding events,
    - stability of the riverbed
    - the depth of cover and likely threat from third party activity
    - the worst case of length of unsupported pipeline
    - the distance to and size of population centres
- The review ensures the risk is managed to an acceptable level. A hard enforcement of 1.2m would significantly increase the number of interventions many of which may be diversions due to local environment agency restrictions on working in water courses.
- Where the depth of cover is less than 0.6m, remedial action is required to reinstate cover wherever possible. Where this is not possible due to

environmental constraints or limitations of the topography, other actions are considered.

33.10. The volumes of investment for the period have been determined based on:

- time based inspections
- the number and type of defects currently identified
- the number of defects forecast to arise during the investment period, the basis for this being the historic rate found over the last 10 years. It is forecast that any remedial intervention will be reinstatement of the ground cover.

33.11. The investment proposed during the period is to:

- Undertake the 5 yearly inspections of all the watercourse crossings and monitor those 47 that have less than 0.6m of cover together with any that arise during the investment period.
- Remediate the 9 issues that are currently identified. Remediate up to a further 18 that are predicted to arise during the period (based on the number identified during RII0-1). All of these remediations are predicted to be Reinstatement of Cover. There are no diversions or replacements within the proposed programme of investment.

Benefits of Investment

33.12. The 9 locations that are currently identified to have depth of cover and spanning will be resolved, together with up to 18 that are forecast to occur during the period.

33.13. The specific issue with depth of cover at Duddon Estuary will be resolved.

Preferred Option

33.14. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for pipelines across water courses in the investment period. [redacted]:

Intervention Options – Watercourse Crossings

[redacted]		
[redacted]		
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

Asset Health Spend Profile

33.15. The profile of investment in the management of pipelines crossing watercourses, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

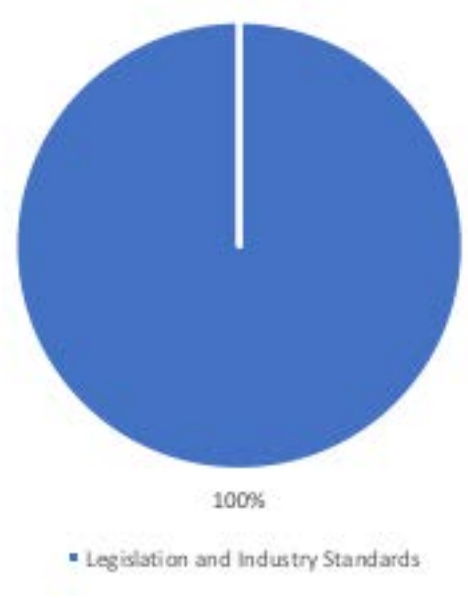
Investment Profile – Watercourse Crossings

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Watercourse Crossing Defects	1,113	431	186	186	186	186	186	186	186	186
Total	1,113	431	186	186	186	186	186	186	186	186
	2,100					**928**				

Intervention Drivers

33.16. The following chart shows the breakdown of investment across each of the intervention drivers. This shows that all of the investment consists of interventions that are driven by legislation and based on industry standards.

RIIO-2 Watercourse Crossings Intervention Drivers[7]



Preferred Programme CBA

33.17. We are targeting an appropriate level of asset health investment to mitigate the safety and environmental risks from an ageing asset base.

33.18. In line with HM Treasury Green Book advice and Ofgem guidance we have appraised whether investment in watercourse crossings is value for money. We have considered costs over a 45-year period in a full cost benefit analysis (CBA).

33.19. The CBA for the watercourse crossings over the period is cost beneficial over the 45-year period. This investment pays back within 10 years, and over 45 years is significantly cost beneficial. This is shown below.

Cost Benefit Analysis – Watercourse Crossings[8]

[7] See Appendix A for intervention driver category definitions

[8] A14.17.5 Watercourse Crossings CBA

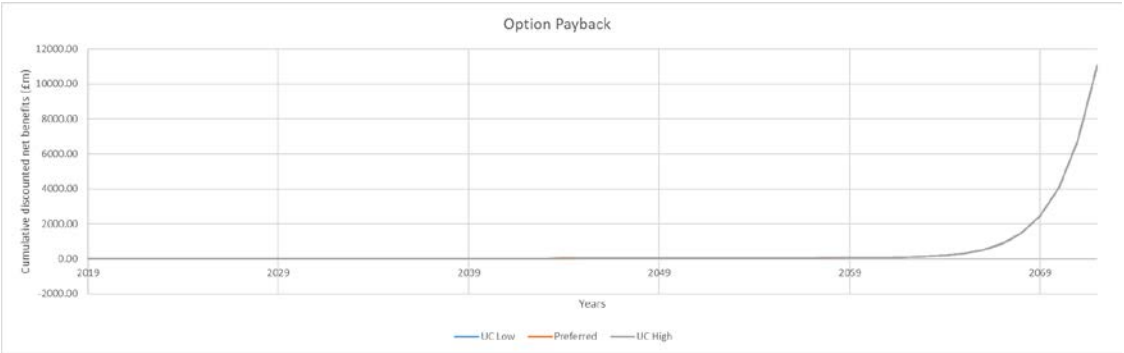
	10 years	20 years	30 years	45 years
Present Value costs (£m)	£1.31	£1.91	£2.27	£2.76
Present Value H&S benefits (£m)	£0.43	£1.34	£2.59	£71.54
Present Value non H&S benefits (£m)	£4.22	£14.89	£32.66	£444.96
Net Present Value (£m)	£3.34	£14.33	£32.97	£513.74

33.20. We have challenged whether this is the right programme of work. Through our asset management processes, we have assessed whether our plans are the best mix of interventions for our stakeholders and consumers.

33.21. The investment proposed in water course crossings is the least whole-life cost programme required to maintain compliance and ensure we manage safety and environmental risk. It will ensure we deliver the outcomes that consumers and stakeholder tell us they want us to meet.

33.22. We have used the potential range of unit cost variance to assess the sensitivity of the Cost Benefit Analysis to the upper and lower limits. Whilst the level of cost benefit and the payback period changes as the unit costs vary, the investment remains cost beneficial across the range of unit costs. The potential variation in unit costs does not cause our decision of the level of investment to be changed.

Net Benefits of Upper and Lower Unit Cost Sensitivity



33.23. Across our stakeholders there is little support for keeping the costs the same as in RIIO-1, given the unacceptable consequential increase in risk.

34. Water Course Crossings - Preferred Option Scope

34.1. The section summarises our preferred investment plan required to deliver acceptable and affordable outcomes for our stakeholders.

Preferred Option

34.2. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for pipelines across water courses in the investment period. [redacted]:

Intervention Options – Watercourse Crossings

[redacted]		
[redacted]		
[redacted]		
[redacted]		

Asset Health Spend Profile

34.3. The profile of investment in the management of pipelines crossing watercourses, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

Investment Profile – Watercourse Crossings

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Watercourse Crossing Defects	1,113	431	186	186	186	186	186	186	186	186
Total	1,113	431	186	186	186	186	186	186	186	186
	2,100					**928**				

Delivery

34.4. At this point in time the delivery of our RIIO-2 and RIIO-3 plans are in principle deliverable based on initial assessments of work. We will regularly review the plan to consider any known or changing constraints, customer impacts and bundling opportunities. In the event of churn our plan must be reoptimised to reflect the impact of the change and provide an opportunity to reconsider the efficient timing of delivery.

34.5. We recognise that many of our asset classes are co-located across the NTS pipe network and sites. Much of our investment delivery also requires outages of the associated pipelines or plant and equipment. The availability of outages is extremely limited across most of the NTS due to the radial nature of the network. It is therefore most efficient from both financial and network risk points of view to bundle investment across asset classes within the same outage period and this may involve taking an outage on a large section of pipework and working on multiple assets/workfaces simultaneously. To achieve this the assets need to be isolated, vented, repaired/replaced and then returned to service for the duration of their technical lives without further intervention a period which could be in the region of 25 years. The cost of recompression for a large section of the network is estimated to be in the region of

£0.25m. A systematic approach therefore maximises the work undertaken in any outage whilst ensuring efficient delivery through minimised project overheads.

34.6. This approach is particularly effective when applied at a feeder level or for a whole site. In which case the preparatory inspection, investigation, risk assessment, planning and procurement activities can be completed as far as possible before the outage. This allows the maximum amount of intervention and risk reduction to be bundled into a single 'campaign' across the length of the feeder. During RIIO-1 this has proved to be an extremely efficient and effective approach to delivery of our programmes of work.

34.7. We recognise that whilst this is in many cases the most efficient method of delivery there are still individual or groups of assets that present a risk to our performance that do not 'fit' into the planned 'campaign' approach. We will ensure that these risks are remediated as efficiently as possible through individual or small groups of targeted interventions.

34.8. A small number of locations on the network require an alternative solution to the usual outage approach to mitigate the risk of disruption to customer supply. This could be for example due to customers on single network spurs. While it may be possible in some cases to negotiate commercial solutions to this, costs per day are expected to be significant and it is likely that an alternative asset solution will be required in the form of stopples (bypasses). We will seek to identify alternative more efficient solutions with our delivery units and suppliers as the nature of the interventions on each site becomes clearer through our survey work.

34.9. Where asset interventions do not require outages then the campaign approach will still be applied to maximise the opportunity for delivery of the same type of work across many locations. This enables efficient procurement through significant volumes of common works.

Depth of Cover (£1.1m)

35. Depth of Cover - Summary

35.1. Most the pipeline is buried and the depth of ground cover above the buried NTS pipeline is essential to managing the risk of damage to the pipeline by third parties. This enables our compliance with PSR.

Pressure Ratings

35.2. The depth of ground protects the NTS Pipeline which operates at a maximum operating pressure between 70 and 94 bar.

36. Depth of Cover - Problem Statement

36.1. Over time the level of ground cover above the pipeline can be eroded which presents an increased risk of third-party damage to the Pipeline. This in turn presents a risk to its structural integrity and any associated potential safety and environmental implications.

Drivers for Investment

36.2. The key drivers for investment in the depth of cover are:

- Erosion of cover above the Pipeline increasing the risk of third-party damage
- PSR Legislation.

36.3. **Erosion of Cover** - Over time the level of cover over the pipeline may erode. This erosion is due to several factors including:

- Land use e.g. ploughing, excavation etc.
- Natural Erosion due to wind, flooding etc.

36.4. Without sufficient cover, the pipelines are susceptible to damage from third party interference.

36.5. **PSR Legislation -** The key driver for investment in maintaining the depth of cover is to ensure compliance with PSR to protect members of the public.

Impact of No Investment

36.6. In appraising asset health investment, we have considered how assets can impact on several outcomes:

- Reliability risk
- Environmental risk
- Safety risk
- Societal risk.

36.7. A critical part of our appraisal method is to assess the baseline position. This is the position where we do not invest proactively in our asset base (i.e. we fix on fail), ensuring any reactive investment meets all health and safety requirements. The baseline position under each area of spend is reactive opex only, with no capex included in the baseline. This is a baseline against which the incremental investment is compared to the incremental benefits. This is critical for developing value for money business plans.

36.8. Lack of investment in the inspection of depth of cover for the pipeline will lead to an unknown level of risk of third-party damage to Pipelines in these areas.

36.9. Any current or future issues of reduced cover will continue to deteriorate and present an increasing risk of damage to the Pipeline. This could lead to the loss of containment

of high-pressure gas and the associated impact on public safety, the environment and the effective operation of the NTS.

36.10. The Do-Nothing position does not support stakeholders and consumer's priorities to maintain or reduce risk levels across all our assets. We have discussed with our stakeholders a range of options around asset health. Stakeholders are clear that they do not want to see any worsening of risk levels and would welcome continual improvements. Hence the increase in risk under the Do-Nothing position is unacceptable to our consumers and stakeholders, who have consistently told us safety is one of their highest priorities.

Examples of the Problem

36.11. [redacted].

Pipeline depth of burial

Spend Boundaries

36.12. The proposed investment applies all the NTS that is buried. The investment includes for reinstatement of depth of cover other minor protective measures, any significant issues that fall outside of the historical norms are not included.

37. Depth of Cover - Probability of Failure

37.1. Several Pipelines assets are defined as only delivering consequential interventions based upon the following definitions:

> *"Any intervention on a network asset, or other infrastructure asset, that modifies the probability of failure, or consequence of failure of **another network asset**. A consequential asset can include, for example:*
>
> - *installation or removal of physical infrastructure designed to prevent damage to adjacent assets in the event of an asset failure (e.g. installation of a blast wall),*
> - *addition or disposal that increases or decreases the resilience of a local or regional network and hence modifies the consequence of failure of other asset(s) in the locality or region."*

Consequential Interventions

37.2. These assets, that reduce or increase the PoF of the associated pipeline asset, are listed in the table below:

Depth of Cover Driver

NARMs Asset Intervention Category	Secondary Asset Class
Consequential Interventions (Non-risk tradeable)	Impact Protection

37.3. Our NOMs Methodology attempts to model the indirect benefits delivered by these assets in terms of the reduction in PoF or Consequence of Failure (CoF) upon a related and/or adjacent asset (e.g. the benefit of air intakes on the numbers of compressor trip and vents). These quantified, but indirect, impacts are used within the CBAs accompanying this justification report but are not considered to be reliable enough for use as a NARMs monetised risk metric.

Depth of Cover Interventions

37.4. The intervention options for Depth of Cover are shown in the table below:

Depth of Cover Interventions

Intervention	SAC	Intervention Category
A22.16.1.1 / Depth of cover (defect resolution)	Impact Protection	Minor Refurbishment

Data Assurance

37.5. All PoF and CoF values are taken from the National Grid Gas Transmission 'Methodology for Network Output Measures' (the Methodology). The Methodology was originally submitted for public consultation in April 2018, with three generally favourable responses received in May 2018. On this basis, Ofgem were happy to provisionally not reject the Methodology pending further work to:

- Produce a detailed Validation Report, confirming the validity of data sources used in the Methodology
- Test a range of supply and demand scenarios and incorporate an appropriate scenario to best represent Availability and Reliability risk

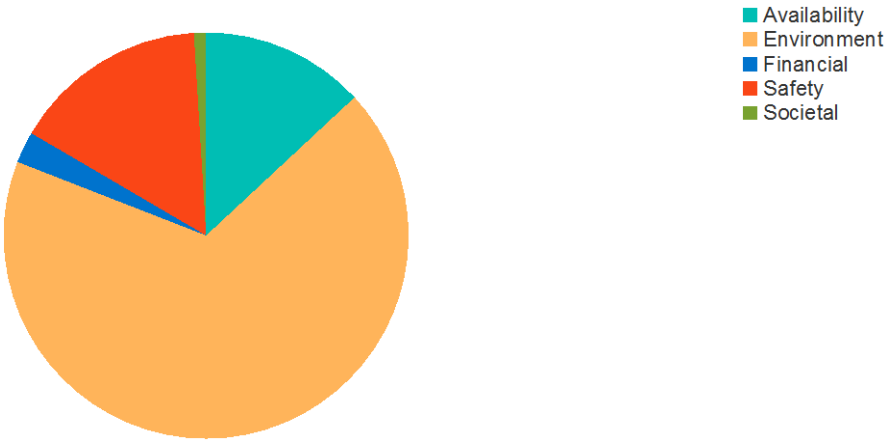
37.6. A review of the Methodology by independent gas transmission experts has been carried out and several improvements identified and incorporated.

37.7. At the time of writing, the final Validation Report has been submitted to Ofgem. We understand that once this work is complete Ofgem will formally “not reject” the Methodology and a License change progressed to restate our RIIO-1 targets in terms of monetised risk commenced.

38. Depth of Cover - Consequence of Failure

38.1. The pie chart below shows the stakeholder impacts expected from failures occurring due to inadequate depth of cover. The charts show the relative numbers of consequence events, not relative monetised risk.

Stakeholder Impacts – Depth of Cover Failures



38.2. The contribution of individual service risk measures towards the overall risk for Depth of Cover can be explained as follows, in order of significance. Depth of Cover benefits are assessed in terms of the level of protection they provide to the primary pipeline asset:

- Environmental risk is associated with the loss of gas arising from a leak or rupture of the pipeline caused by external interference (or potentially corrosion)
- Safety risk is associated with the potential for third-party damage, or external interference, causing a pipeline leak or rupture. The risk of an external interference event is much more likely with a low depth of pipeline cover. Where the pipeline passes near centres of population the Safety risk arising from ignition of the leak or rupture is relatively large. Corrosion risk is also higher with a reduced depth of cover.
- Availability risk is associated with the potential outages associated with the shut-down of a pipeline for repair of a leak or rupture caused by external interference.
- Financial risk is mostly associated with the costs of operating and maintaining the network at the current level of risk
- Societal risk is largely associated with disruption to road or rail transportation following asset failure. The likelihood of a fire or explosion is small and many assets are not near to transportation links. Therefore, the overall societal risk associated with pipeline asset failure is small.

38.3. All Pipeline asset intervention benefits have been assessed per-piggable section, which relates to a length of pipeline and associated secondary assets between pig traps, which are present on Above Ground Installation (AGI) sites. This assumption was made to capture the full benefit of an ILI survey and associated defect correction. This will be normalised to a per-kilometre measure for NARMs benefits reporting.

39. Depth of Cover - Options Considered

39.1. In this section, we outline the options we have considered.

Potential Intervention Options

39.2. In addition to the interventions that apply to all Pipelines, the following intervention categories apply to areas of low depth of cover:

39.3. **Detailed Site Visit –** where the aerial of ground-based surveys of the pipeline identify a potential issue of ground cover then a detailed site visit and depth survey is undertaken.

39.4. **Immediate Actions – i**mmediate interventions to reduce the risk to damage to the pipeline:

- advice to the landowner
- installation of marker posts
- installation of localised protection
- minor reinstatement of small areas of ground cover
- where it is considered that that the pipeline integrity is at risk within the subsequent 12 months from 3rd party activities such as agricultural / drainage or other works, then the affected area is fenced off to prevent activities above the pipeline.

39.5. **Reinstatement of Cover -** Replace cover the on the pipeline. This reduces the risk of mechanical damage.

39.6. **Replace -** Replace the affected section of the Pipeline with a new section of heavy walled pipe. This heavy walled pipe mitigates the impact of any third-party strike on the pipeline.

39.7. **Diversion -** lay a new section of Pipeline along an alternative route to avoid the issues at the current location.

Intervention Unit Costs

39.8. The total RIIO-2 investment for the Depth of Cover represents 1% of the Pipelines investment theme. The unit costs that support the Depth of Cover investment have been developed using other estimation methods due to the spectrum of variances in the works that can be performed making obtaining supplier quotations difficult and unpractical.

39.9. The table below provides the unit costs for all interventions to mitigate the risks of loss of depth of cover over the pipeline assets.

Unit Costs for Interventions – Depth of Cover

Intervention	Cost (£)	Unit	Evidence	Data points	Overall value in BP
Depth of Cover					
A22.16.1.1 / Depth of cover (defect resolution)	[redacted]	Per defect	Estimated – Other	1	£1,081,724

40. Depth of Cover - Programme Options

40.1. Based on our experience the only credible programme option that maintains compliance and manages the risk on the NTS is to monitor depth of cover and reactively invest in issues that are identified.

40.2. For RIIO-2 and RIIO-3 the only intervention option that has been considered and included to resolve any identified issues is to reinstate the level of cover over the pipeline. This is the lowest whole life intervention to resolve the issue, manage the risk on the NTS and comply with legislation. There are no diversions or replacements within the proposed programme of investment. Whilst further options could be considered, due to the nature of these assets and the simplicity of the interventions to be done, it is not prudent or affordable to consider options which would add unnecessary cost to the plan. We have therefore not considered any further programme options as any of those would be an increase in initial investment and overall whole life cost from this proposed position.

41. Depth of Cover - Business Case Outline and Discussion

41.1. In this section, we set out our overall investment plan for depth of cover remediation. This section demonstrates why the proposed investment levels are the right levels to ensure the health and reliability of these assets for the investment period and beyond.

Key Business Case Drivers Description

41.2. The investment in depth of cover for the pipeline is driven by safety legislation together with third party activity and the environment surrounding and impacting the Pipeline.

41.3. Therefore, in developing our risk forecasts and proposed plans we have considered the impact of the following drivers for investment in the watercourse crossings are:

- Erosion of cover above the Pipeline increasing the risk of third-party damage
- PSR Legislation.

41.4. Considering these drivers ensures that we develop plans that meet our legal obligations to intervene and prioritise the right assets for investment.

Business Case Summary

41.5. In appraising asset health investment, we have considered how assets can impact on several outcomes:

- Reliability risk
- Environmental risk
- Safety risk
- Societal risk.

Outcomes Delivered

41.6. Lack of depth of cover for the pipelines can impact these outcomes. More specifically, the outcome of investment in depth of cover:

- Ensures continued compliance with PSR Legislation to protect members of the public.
- Protect the integrity of our pipelines asset.

Stakeholder Support

41.7. Consumer and stakeholder research and engagement has been integral to the development of our asset health investment plans. Early discussions realised that to engage in meaningful dialogue, our plan outputs should be presented at a programme rather than asset level of detail. This is due to the integrated nature of our Asset Health plan which makes it challenging to disaggregate and engage on individual elements. For details of our stakeholder engagement approach please refer to ‘I want to take gas on and off the system where and when I want’ [Chapter 9 of the GT submission].

Investment Decision Approach

41.8. To deliver the outcomes for the investment period the depth of cover from pipelines require:

- The normal pipelines aerial and walking inspections identify potential areas of low ground cover.
- Reduced depth of cover is considered as <0.9m for pipelines constructed up to and during 1984 and <1.1m for pipelines constructed during or after 1985. This is based upon IGEM/TD/1. Where inspections show that the depth of cover is below this or other issues exist then a risk-based review is undertaken. This review includes:
  - the depth of cover and likely threat from third party activity
  - land type and usage
  - age of pipeline
  - the distance to and size of population centres
- The review ensures that the threat of damage to the pipeline is managed to an acceptable level.

41.9. The volumes of investment for the period have been determined based on:

- the number and type of defects currently identified
- the number of defects forecast to arise during the investment period, the basis for this being the historic rate found over the last 10 years. It is forecast that any remedial intervention will be reinstatement of the ground cover.

41.10. The investment proposed during the period is to:

- Monitor the locations that have identified problems with depth of cover together with any that arise during the investment period.
- Remediate the issues that are currently identified together with any that arise during the period, through the reinstatement of the cover over the pipeline.

Benefits of Investment

41.11. The locations that are currently identified to have depth of cover issues will be resolved, together with those that are forecast to occur during the period.

Preferred Option

41.12. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the mitigating the risks of loss of depth of cover in the investment period. [redacted]:

Volumes of intervention

Asset Health Spend Profile

41.13. The profile of investment in the management of depth of pipeline cover, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

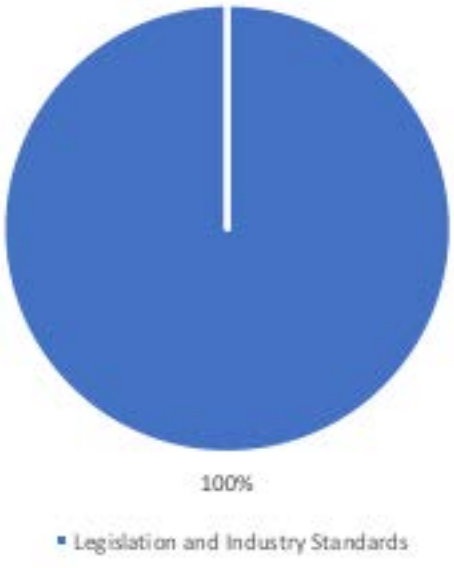
Investment Profile – Depth of Pipeline Cover

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Impact Protection	280	280	280	120	120	120	120	120	120	120
Total	280	280	280	120	120	120	120	120	120	120
	1,082					**601**				

Intervention Drivers

41.14. The following chart shows the breakdown of investment across each of the intervention drivers. This shows that all of the investment consists of interventions that are driven by legislation and based on industry standards.

RIIO-2 Depth of Cover Intervention Drivers[9]



Preferred Programme CBA

41.15. We are targeting an appropriate level of asset health investment to maintain risks across our ageing asset base.

[9] See Appendix A for intervention driver category definitions

41.16. In line with HM Treasury Green Book advice and Ofgem guidance we have appraised whether investment in depth of cover is value for money. We have considered costs over a 45-year period in a full cost benefit analysis (CBA).

41.17. The CBA shows that investment in these assets is cost beneficial over the 45-year period. This investment pays back within 10 years, and over 45 years is clearly cost beneficial. This is shown below.

Cost Benefit Analysis[10]

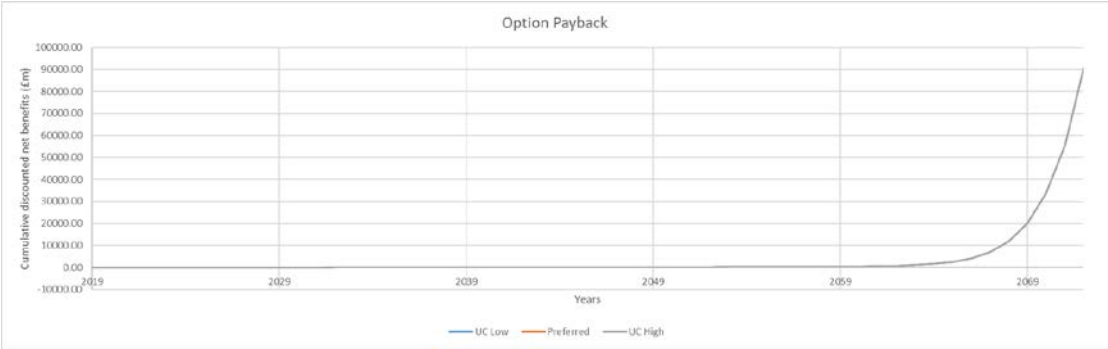
	10 years	20 years	30 years	45 years
Present Value costs (£m)	£0.68	£1.02	£1.22	£1.48
Present Value H&S benefits (£m)	£2.71	£8.72	£17.58	£580.37
Present Value non H&S benefits (£m)	£31.85	£114.50	£256.20	£3,627.26
Net Present Value (£m)	£33.88	£122.20	£272.56	£4,206.14

41.18. We have challenged whether this is the right programme of work. Through our asset management processes, we have assessed whether our plans are the best mix of interventions for our stakeholders and consumers.

41.19. The investment proposed in depth of cover is the least whole-life cost programme required to maintain compliance and ensure we manage safety risk. It will ensure we deliver the outcomes that consumers and stakeholder tell us they want us to meet.

41.20. We have used the potential range of unit cost variance to assess the sensitivity of the Cost Benefit Analysis to the upper and lower limits. Whilst the level of cost benefit and the payback period changes as the unit costs vary, the investment remains cost beneficial across the range of unit costs. The potential variation in unit costs does not cause our decision of the level of investment to be changed.

Net Benefits of Upper and Lower Unit Cost Sensitivity



41.21. Across our stakeholders there is little support for keeping the costs the same as in RIIO-1, given the unacceptable consequential increase in risk.

[10] A14.17.1 Depth of Cover CBA

42. Depth of Cover - Preferred Option Scope

42.1. The section summarises our preferred investment plan required to deliver acceptable and affordable outcomes for our stakeholders.

Preferred Option

42.2. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the mitigating the risks of loss of depth of cover in the investment period. [redacted]:

Volumes of intervention

[redacted]

Asset Health Spend Profile

42.3. The profile of investment in the management of depth of pipeline cover, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

Investment Profile – Depth of Pipeline Cover

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Impact Protection	280	280	280	120	120	120	120	120	120	120
Total	280	280	280	120	120	120	120	120	120	120
	1,082					**601**				

Delivery

42.4. At this point in time the delivery of our RIIO-2 and RIIO-3 plans are in principle deliverable based on initial assessments of work. We will regularly review the plan to consider any known or changing constraints, customer impacts and bundling opportunities. In the event of churn our plan must be reoptimised to reflect the impact of the change, and provide an opportunity to reconsider the efficient timing of delivery.

42.5. We recognise that many of our asset classes are co-located across the NTS pipe network and sites. Much of our investment delivery also requires outages of the associated pipelines or plant and equipment. The availability of outages is extremely limited across most of the NTS due to the radial nature of the network. It is therefore most efficient from both financial and network risk points of view to bundle investment across asset classes within the same outage period and this may involve taking an outage on a large section of pipework and working on multiple assets/workfaces simultaneously. To achieve this the assets need to be isolated, vented, repaired/replaced and then returned to service for the duration of their technical lives without further intervention a period which could be in the region of 25 years. The cost of recompression for a large section of the network is estimated to be in the region of £0.25m. A systematic approach therefore maximises the work undertaken in any

outage whilst ensuring efficient delivery through minimised project overheads. As a general approach outage work for pipelines will be aligned to ILI digs which take place at defined intervals between four and fifteen years.

42.6. This approach is particularly effective when applied at a feeder level or for a whole site. In which case the preparatory inspection, investigation, risk assessment, planning and procurement activities can be completed as far as possible before the outage. This allows the maximum amount of intervention and risk reduction to be bundled into a single 'campaign' across the length of the feeder. During RIIO-1 this has proved to be an extremely efficient and effective approach to delivery of our programmes of work.

42.7. We recognise that whilst this is in many cases the most efficient method of delivery there are still individual or groups of assets that present a risk to our performance that do not 'fit' into the planned 'campaign' approach. We will ensure that these risks are remediated as efficiently as possible through individual or small groups of targeted interventions.

42.8. A small number of locations on the network require an alternative solution to the usual outage approach to mitigate the risk of disruption to customer supply. This could be for example due to customers on single network spurs. While it may be possible in some cases to negotiate commercial solutions to this, costs per day are expected to be significant and it is likely that an alternative asset solution will be required in the form of stopples (bypasses). We will seek to identify alternative more efficient solutions with our delivery units and suppliers as the nature of the interventions on each site becomes clearer through our survey work.

42.9. Where asset interventions do not require outages then the campaign approach will still be applied to maximise the opportunity for delivery of the same type of work across many locations. This enables efficient procurement through significant volumes of common works. For pipelines this may include some work associated with depth of cover and/or river crossing remediation. CIP surveys are unlikely to require outages and the requirement for nitrogen sleeve outages will vary from case to case.

Appendices

Appendix A – Intervention Driver Categories

Intervention Driver Categories

	Name	Definition
A	Legislation & Industry Standards	Intervention required to ensure compliance with relevant safety legislation and/or adopted industry standards.
B	OEM Guidance	Intervention recommended by OEM to maintain intended asset performance and safe operation. Any deviation from this guidance shall be specifically risk-assessed to ensure compliance with relevant safety legislation.
C	Internal Policy	Internal policy defined intervention required to maintain asset performance, and to align with relevant safety legislative requirements